BIOLOGY

STUDENT TEXTBOOK
GRADE 12

2023

FEDERAL DEMOCRATIC REPUBLIC OF ETHIOPIA
MINISTRY OF EDUCATION

BIOLOGY STUDENT TEXTBOOK GRADE 12

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Biology

STUDENT TEXTBOOK
GRADE 12

Writers:

Anbessa Dabassa (PhD)

Eba Alemayehu (PhD)

Pedagogical Editor:

Meskerem Cheru (MSc)

Content Editor:

Destaw Damtie (PhD)

Language Editor:

Yenus Nurie (PhD)

Illustrator:

Nega Tassie (PhD)

Designer:

Ali Seid (PhD)

Evaluators:

Berhanu Tesfaye (MA & MEd)

Gebrehana Zeleke (MSc)

Samuel Desalegn (MSc)

Bekele Geleta (MSc)

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Unit 1: Applications of Biology

Unit learning outcome

At the end of this unit, the will be able to:

- Define biotechnology.
- Describe conservation of natural resources
- Describe fuud and nutrition security
- Explain conscious citizen and global citizen
- Describe biotechnology and genetic engineering
- Explain the role of biotechnology to secure the food of the society
- Explain some of the traditional uses of biotechnology
- Explain the role of microorganisms in making bread, teji, tella, wine and beer
- Describe the application biotechnology in agriculture
- Explain what genetically modified organisms means
- Describe the benefits of creating transgenic crops.
- Describe the application of environmental biotechnology
- explain the process and importance of gene therapy
- explain bioremediation and biopesticides.
- Explain the modern application of biotechnology

UNIT 1: APPLICATION OF BIOLOGY

The applications of biology in our daily to day life are numerous. Biology is the science in charge of studying all living beings. It helps us to understand every living organism, from the smallest bacteria to the blue whales. Biologists often focus on a different subset of living organisms, such as birds, plants, or bacteria, to determine their character.

Biological science is very useful science to determine where some diseases and pests come from, such as infections, animal pathologies, and damage to plants. Biology covers the study of the functions of living organisms, the evolution of species, the factors that produce diseases, as well as the discovery of new drugs.

This discipline allows human beings to explore topics such as genetic engineering, research applications with mother cells, and global warming. It also helps to understand nature and how humans, animals, and plants interact in life.

Biology offers a vision of how living things evolve. Understanding the rates of extinction and how a species depends on and affects the habitat where it lives improves the effectiveness of conservation efforts.

A practical application of biology with which most people are familiar is hand washing, domestication, and traditional fermentation. Regular soap washing removes acquired microbes from the skin and helps control the spread of infectious diseases.

In addition, another application of biology is the set of instructions given to take all the pills of antibiotics in a recipe. Then, to broaden your understanding of this further you will look at the more everyday examples of the application of this science in the next topics.

1.1. Application in Conservation of natural resources

After the successful completion of this section, you will be able to:

- Define natural resources.
- Identify renewable and non-renewable resources.
- Classify natural resources as renewable and non-renewable.
- Describe the role of conservation in protecting and preserving our natural environment.
- Discuss the role of Biology in the conservation of natural resources

Keywords

Natural resources: resources (actual and potential) supplied by nature

Renewable: Capable of being produced indefinitely. It will not be used as there will always be more available.

Non-renewable: There is a definite amount available. Once used, it cannot be easily made or replaced.

Extinct: No longer in existence.

Conservation: the act of preserving, guarding or protecting

Extinict: No longer in existence

Conservation is the careful maintenance and wise use of natural resources to prevent them from disappearing. Natural resources are physical supplies that exist in nature and include soil, water, air, plants, animals, and energy. Conservation biology is a mission-oriented science that focuses on how to protect and restore biodiversity, or the diversity of life on Earth. Ethiopia has many natural resources, such as, gold, platinum, potash, limestone, natural gas, coal, in addition to lakes, volcanic ocean, and water falls (Figure 1.1). Timber, many different crop plants, coffee plantations, many different species of animals and plants, and many different birds, make up rich ecosystems (Figure 1. 2).

Self-questioning

- Do you agree with the conservations of natural resources? Why?
- Explain the concept that human should practice sustainable management of natural resources?
- How the knowledge and application of conservation is critical to the survival of our people?

Natural resources can be classified as renewable or non-renewable. Renewable resources are mainly living things and their products. The main sources of renewable resources are sun, wind, water, the earth's heat (geothermal) and biomass (which relates to living things). When managed carefully, they can be used, reused and replaced. Examples of renewable resources are crop plants, trees, cattle, and chickens. Non-renewable resources are natural substances that are not replaced at the same speed as that are used up. They are finite resources. Examples of non-renewable resources include metals such as gold and iron and fossil fuels such as oil, natural gas, and coal.

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Hawassa Lake ` Volcanoes with sulfur deposits in Ethiopia (Ertale) Tis Abay

Figure 1.1. Natural landscapes in Ethiopia

Conserve the non-renewable natural resources of Ethiopia is economically advantageous to mine metals and fossil fuels, doing so have a negative impact on the the earth (i.e. climate change) and that by conserving them instead and using renewable energy sources would be more beneficial to the planet. Even renewable

resources can be lost if we do not manage them carefully. What should be done to conserve trees? coppicing and having a continual cycle of planting trees to replace the ones being cut down, bearing in mind that there is a lag time for trees to grow.

Therefore, biologists takes a position in conserving species and saving them from extinction through the preservation of animals and plants in terms of zoos and seed banksand by stopping the destruction of their natural habitats so the populations are able to thrive.

Activity 1.1: Work in group and report what are natural resources of Ethiopia and discuss their economic importance

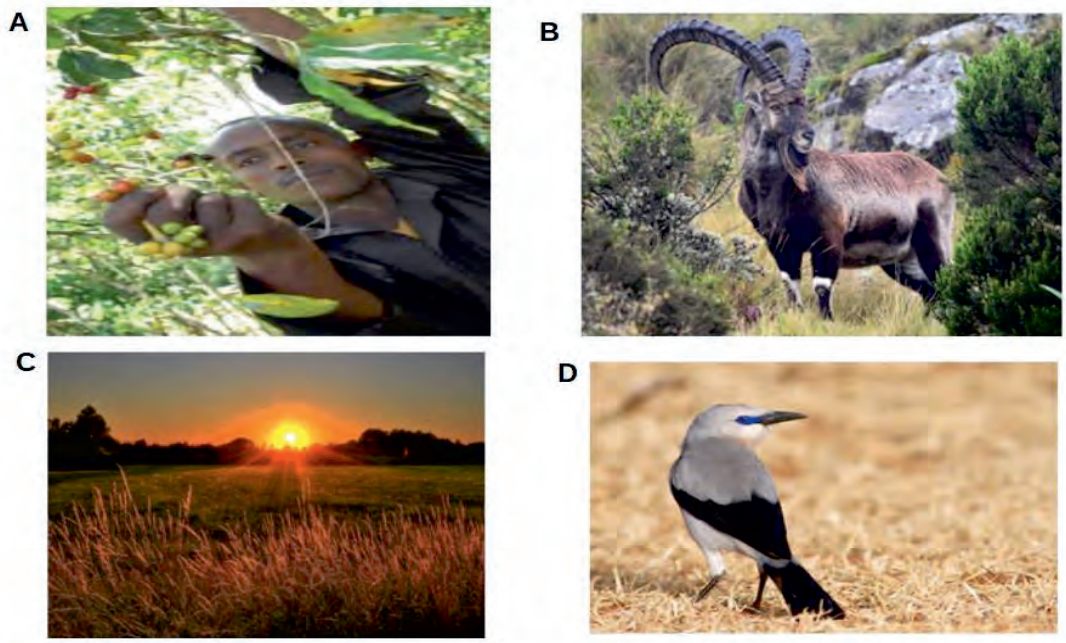


Figure 1.2. Some important renewable resources in Ethiopia: Coffee (a), Walia Ibex (*Capra walie*) (b), Sunlight as a source of energy (c), Ethiopian Bush crow (*Zavattariornis stresemanni*).

To protect our natural resources, both in Ethiopia and around the world, become more aware of the need for the conservation of natural resources, both non-renewable and renewable. Conservation is protecting and preserving our natural environment so that non-renewable resources are used sparingly, and renewable resources should be appropriately managed. Otherwise, they can last for an extended period of time in the future

Activity 1.2: Natural resources of Ethiopia

Have a brainstorming session and think of as many natural resources of Ethiopia as you can. Given that read what the types of renewable and non-renewable resources are, and specify with a specific examples. Forexample name rivers, wind that goes across named plain, and natural gas from named place.

Now divide them up into renewable resources and nonrenewable resources.

Make a poster or collage to show these natural resources. Divide the poster into renewable and non-renewable resources.

1.2. Food and nutrition security

After the successful completion of this section, you will be able to:

- Define food security.
- Practice school-based gardening as one strategy of addressing food security.

Food security, as defined by the United Nations' Committee on World Food Security, is a state in which when all the people have physical, social, and economic access to sufficient, safe, and nutritious food that meets their food preferences and dietary needs for an active and healthy life at all times. However, food insecurity is often rooted in poverty and has long-term impacts on the potential of families, communities, and countries to develop and prosper. Prolonged undernourishment stunts growth (Figures 1.4 & 1.5), slows cognitive development and increases susceptibility to illness.

Key word

Food Security: The state in which all people have physical, social and economic access to sufficient, safe and nutritious food.

Self-questioning

- Which biological application is important for maintaining food security?

Nutrition security is a situation whereby individuals have access to sufficient, safe and nutritious foods, safe water and adequate sanitation, the ability to access health care services, and knowledge of sound household and community practices in child care, food storage and preparation and hygiene.

Therefore, food security is ensured only if: enough food is available for all in a county; when all individuals have the capacity to buy food of acceptable quality, and when there is no barrier to access food. Therefore, Biology plays a key role in producing high-nutrient staple crops and developing new products that can combat malnutrition, and thereby improving food utilization. Biotechnologests design the manufacturing processesand machinery used to produce food and drink. Biologists work to ensure food security within a country, and across the world, through these innovations. This allws ptoducts to have consistant flavor, color, and texture to be produced in large quantities.

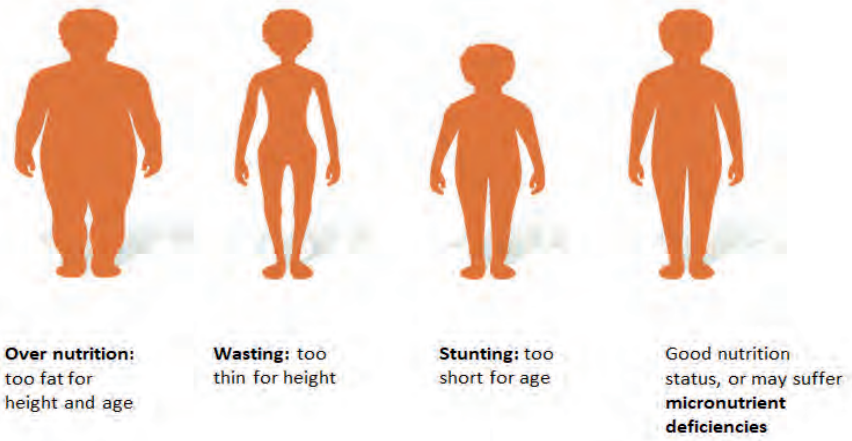


Figure 1.3 Types of mal nutrition (Source: FAD 2015)

Activity 1.3a. Individual work.

Write a short set of notes in order to answer the following question(s). Use the internet, as well as digital and print educational resources.

- What factor influence food availability?
- What is the difference between food security, nutritional security, and food insecurity?
- What are the effects of food and nutritional insecurity?

Activity 1. 3b:

Make a group of 5-10 students to grow different vegetables in the school compound on the ground/in pots to easily demonstrate how one can secure food in a small area.

1.3. Creating conscious citizens and ensuring sustainable development

After the successful completion of this section, you will be able to:

- Define conscious citizen.
- Explain the role of biology in creating a conscious citizen.
- Describe the meaning of a conscious global citizen.
- Explain how sustainable development can be ensured AND/OR Define

Conscious citizen: Person who places value on being fully human while connecting with a higher purpose.

A conscious citizen is one who places value on being fully human while connecting with a higher purpose; one who values human life and a relationship with all living things, and one who takes the responsibility for transforming skills into action through ethical decision making, to ultimately improve life and living on the planet. Biology has a vital role in creating conscious citizen by expanding awareness of the social, global, and environmental conditions.

Biology empowers conscious citizens to assume personal responsibility by engaging in and being committed to initiating positive impact. Nowadays, the interplay of biology and technology (biotechnology) has become vital to facilitating sustainable development initiatives and conscious citizens will use biotechnology applications to improve life and living on the planet. Conscious citizen biologists develop innovative and cost effective bio-based technologies which consume fewer resources, incorporate recycling, reuse components and reduce production of wastes, and use strategies for sustaining a greener earth and improving food production.

Self-questioning

- Why do we need to be conscious global citizens?
- How can we become a conscientious citizen?

Activity 1.3c

In a group of 5-10 students, discuss how students like you can be a conscious global citizen. Then prepare a report and present it to the class..

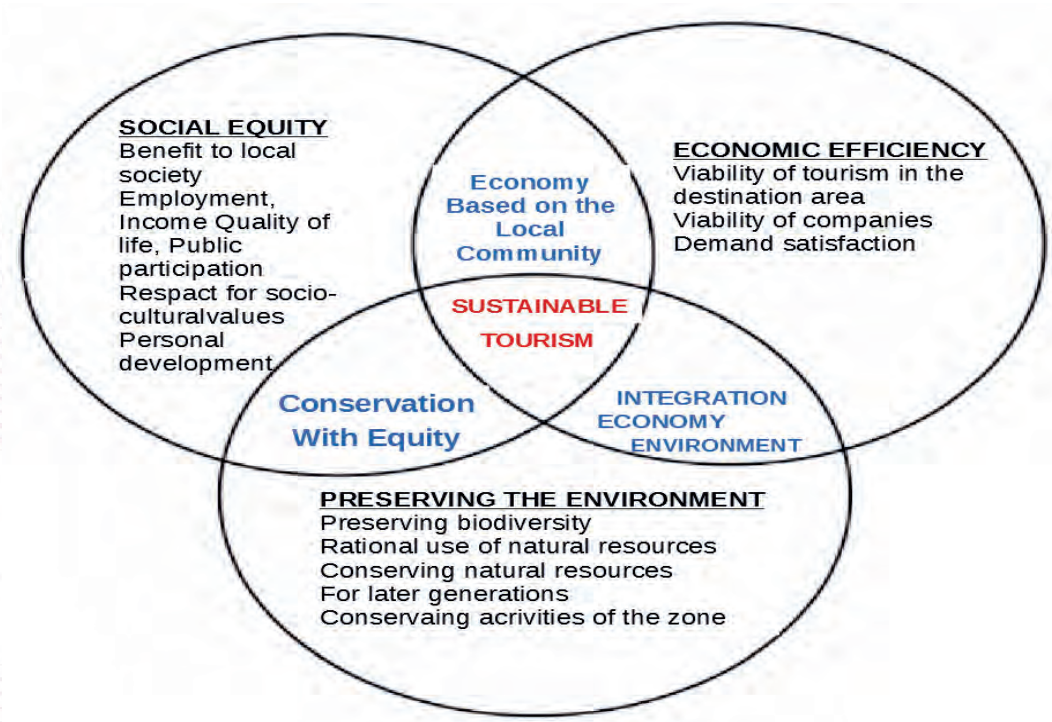


Figure 1.4. A model for sustainable development

According to the World Conservation Union (IUCN, 2006), the three dimensions of sustainability (economic, social and environmental) are represented either as pillars, embedded circles or in the popular Venn diagram (Fig 1.4) of three overlapping circles.

The conscious global citizens (biologists) in Ethiopia involved in sustainable development through protecting, managing and monitoring the existing resources of our land including: analysing soil, water and air for chemical pollution. finding ways to clean up pollution.

identifying, recording and monitoring the plants and animals that share the land we use.

1.4. Applications in biotechnology

Biotechnology is the application of technologies that involve the use of living organisms, or products from living organisms, for the development of products that benefit humans. Genetically modified organisms (GMOs) have received genetic material via recombinant DNA technology. If an organism has received genetic material from a different species, it is called a transgenic organism. A gene from one species that is introduced into another species is called a transgene.

The organisms used may be genetically modifed to make them more suitable. Crops can be modifed to increase yields and to obtain novel products. Biotechnology can be used in the prevention and mitigation of contamination from industrial, agricultural and municipal wastes. Biotechnology can also be used in the diagnosis and treatment of disease.

(i). Application of Biology for Food processing and production

This method involves the increasing of foods productivity using Microorganisms. A technology that shows some promise in increasing world food productivity. Forexample **single-cell protein (SCP)**. This material is produced from waste materials such as molasses from sugar refining, petroleum by-products, and agricultural wastes. In developed countries, an animal feed called Pruteen is produced by mass culture of the bacterium *Methylophilus methylotrophus.* Mycoprotein, a product made from the fungus *Fusarium venenatum,* is also sold there. The filamentous texture of this product makes it a likely candidate for producing meat substitutes for human consumption.

After the successful completion of this section, learner will be able to :

- Define food security.
- Practice/Apply school-based gardening as one strategy of addressing food security.

Health food stores carry bottles of dark green pellets or powder that is a culture of a spiral-shaped cyanobacterium called *Spirulina.* This microbe is harvested from the surface of lakes and ponds, where it grows in great mats. In some parts of Africa, Asia, and Mexico, *Spirulina* has become a viable alternative to green plants as a primary nutrient source. It can be eaten in its natural form or added to other foods and beverages.

Vitamins are also produced using biotechnology. Vitamin C was the first vitamin to be produced during a fermentation process by using **bacteria.** Previously, Vitamin B_{12} or cyanocobalamin and B_2 or Riboflavin were obtained from animal liver extract. But, nowadys the production of vitamin-B_{12} involved fermentation by propionic bacteria. In nature B_2 is found in cereals, vegetables and yeast but the yield of B_2 can be enhanced hundred to three hundred fold by using microbes.

(a). Dairy Products

Microorganisms are used in making a wide variety of dairy products. Cultured buttermilk, popular in the developed countires, is made by adding *Streptococcus cremoris* to pasteurized skim milk and allowing fermentation to occur until the desired consistency, flavor, and acidity are reached. Other organisms—*Streptococcus lactis, S. diacetylactis and Leuconostoc citrovorum, L. cremoris, or L. dextranicum*—make buttermilk with different flavors because of variations in fermentation products. Sour cream is made by adding one of these organisms to cream. Yogurt is made by adding *Streptococcus thermophilus* and *Lactobacillus bulgaricus* to milk. These organisms release still other products, and so yogurt has a different texture and flavor.

Fermented milk have been made for centuries in various countries in the globe, especially Africa, Asia, and Eastern European. The products vary in acidity and alcohol content. Acidophilus milk is made by adding *Lactobacillus acidophilus* to sterile milk. Sterilization prevents uncontrolled fermentation by organisms that might already be present in nonsterilized milk. Bulgarian milk is made by *L. bulgaricus*; it is similar to buttermilk except that it is more acidic and lacks the flavor imparted by the leuconostocs.

(b). Fermented Meats

Microbes such as *Lactobacillus plantarum* and *Pediococcus cerevisiae* add flavor by fermenting meats such as salami, summer sausage, and Lebanon bologna. The heterolactic acid fermentation helps preserve the meat and also gives it a tangy flavor. Fungi such as *Penicillium* and *Aspergillus*, growing naturally on the surfaces of country hams, help to produce their distinctive flavor.

(c). Production of beer, wine, and spirits

Beer and wine are made by fermenting sugary juices; spirits, such as whiskey, gin, and rum, are made by fermenting

juices and distilling the fermented product. Distillation separates alcohol and other volatile substances from solid and nonvolatile substances. Strains of Saccharomyces are the fermenters for all alcoholic beverages. Many different strains have been developed, each having distinctive characteristics. Both the organisms and how they are used are carefully guarded brewers' secrets.

To make beer, cereal grains (usually barley) are malted (partially germinated) to increase the concentration of starch-digesting enzymes that provide the sugar for fermentation. Malted grain is crushed and mixed with hot water (about 65^0C), producing mash. After a few hours, a liquid extract called wort is separated from the mix. Hops (flower cones from the hop plant) are added to the wort for flavoring, and the mixture is boiled to stop enzyme action and precipitate proteins. A strain of Saccharomyces is added. Fermentation produces ethyl alcohol, carbon dioxide, and other substances, including amyl and isoamyl alcohols and acetic and butyric acids, which add to the flavor of the beer. After fermentation, the yeast is removed, and the beer is filtered, pasteurized, and bottled.

Most wine is made from juice extracted from grapes, although it can be made from any fruit and even from nuts or dandelion blossoms. Juice is treated with sulfur dioxide to kill any wild yeasts that may already be present. Sugar and a strain of Saccharomyces are then added, and fermentation proceeds. Although ethyl alcohol is the main product of fermentation, other products similar to those in beer add to the flavor of the wine. In both beer and wine, the particular characteristics of the juice and the yeast strain determine the flavor of the final product. When fermentation is completed, liquid wine is siphoned to separate it from yeast sediment and, if necessary, cleared with agents such as charcoal to remove suspended particles. Finally, it is bottled and aged in a cool place.

Spirits are made from the fermentation of a variety of foods, including malted barley (Scotch whiskey), rye (rye whiskey, gin), corn (bourbon), wine or fruit juice (brandy), potatoes (vodka), and molasses (rum). After fermentation, distilling separates alcohol and other volatile substances that impart flavor from the solid and nonvolatile substances. Because of distillation, the alcohol content of spirits ranges from 40 to 50% much higher than the typical 12% for wine and 6% for beer.

Activity 1.4: Group work

1. Discuss in your groups the ingredients, recipe, and biotechnology of the following traditional fermentation products.

i) Making "*Injera*"

ii) Making "*Areki*"

iii) Making "*Tej*"

iv) Making "*Tella*"

Self-questioning

1. List microorganisms used in each ermentation product and explain why?
2. What type of metabolites or bio-products are produced by those microorganisms?
3. What is back slopping traditional food fermentation? Can you give one example?

(d). Bread making

Microorganisms accomplish three functions in bread making:

1. leavening the flour-based dough,

2. imparting flavor and odor, and

3. conditioning the dough to make it workable.

Leavening is achieved primarily through the release of gas to produce a porous and spongy product. Without leavening, bread dough remains dense, flat, and hard. Although various microbes and leavening agents can be used, the most common ones are various strains of the baker's yeast *Saccharomyces cerevisiae.* Other gas-forming microbes such as coliform bacteria, certain *Clostridium* species, heterofermentative lactic acid bacteria, and wild yeasts can be employed, depending on the type of bread desired.

Yeast metabolism requires a source of fermentable sugar such as maltose or glucose. Because the yeast respires aerobically in bread dough, the chief products of maltose fermentation are carbon dioxide and water rather than alcohol (the main product in beer and wine). Other contributions to bread texture come from kneading, which incorporates air into the dough, and from microbial enzymes, which break down flour proteins (gluten) and give the dough elasticity.

Besides carbon dioxide production, bread fermentation generates other volatile organic acids and alcohols that impart delicate flavors and aromas. These are especially well developed in home-baked bread, which is leavened more slowly

than commercial bread. Yeasts and bacteria can also impart unique flavors, depending upon the culture mixture and baking techniques used. The pungent flavor of rye bread, for example, comes in part from starter cultures of lactic acid bacteria such as *Lactobacillus plantarum, L. brevis, L. bulgaricus, Leuconostoc mesenteroides,* and *Streptococcus thermophilus.* Sourdough bread gets its unique tang from *Lactobacillus sanfrancisc.*

Figure 1.5. sourdough bread

1.5. Genetic Engineering

Genetic engineering is the process of transferring DNA from one organism into another that results in a genetic modification; the production of a transgenic organism. Specific applications of genetic engineering are abundant and increasing rapidly in number. Genetic engineering is being used in the production of pharmaceuticals, gene therapy, and the development of transgenic plants and animals.

a. Animal breeding and transgenic animals, and plants and disease, and pest management

Animal breeding addresses the genetic value of livestock. Selecting for breeding animals with superior traits in growth rate, egg, meat, milk, or wool production, or with other desirable traits has revolutionized the livestock and plant production throughout the entire world (Figure 1.2). Animals can also be genetically modified (transgenic animals) for valuable traits. There are many potential applications of transgenic methodology in developing new and improved strains of livestock. Practical applications of transgenic technology in livestock production include enhancing the prolificacy and reproductive performance, increasing feed utilization and growth rate, improving carcass composition, improving milk production and/or composition, modification of hair or fiber, and increasing disease resistance in animals. The development of transgenic farm animals will allow more flexibility in the direct genetic manipulation of livestock. Gene transfer is a relatively rapid way - of altering the genome of domestic livestock

Figure 1.6. Biotechnology improves the quality of breeds

b. Tissue culture

Plants can be propagated quickly and in large quantity by **tissue culture** technique. Tissue culture, a method of biological research in which fragments of tissue from an animal or plant are transferred to an artificial environment in which they can

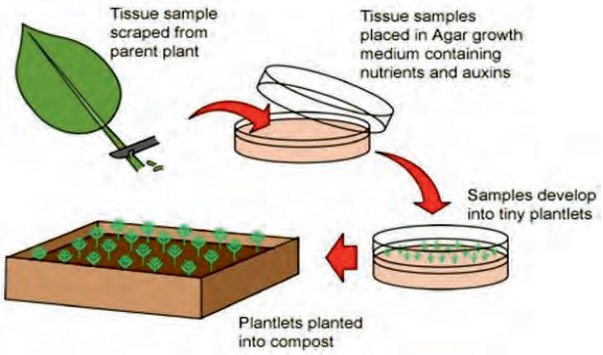


Figure 1.7. Tissue calture

continue to survive and function. The cultured tissue may consist of a single cell, a population of cells, or a whole or part of an organ. Plants produced in large amount using this technique include palm trees, orchids, bananas, and carrots. Using this technology large quantity of food with desired quality can be produced in reasonably little area. Therefore, tissue culture is seen as an important biotechnology for developing countries for the production of disease-free, high quality planting material and the rapid production of many uniform plants. (Figure 1.7).

1.6. Health and wellbeings

Human drugs such as insulin for diabetics, growth hormone for individuals with pituitary dwarfism, and tissue plasminogen activator for heart attack victims, as well as animal drugs like the growth hormones, bovine or porcine somatotropin, are being produced by the fermentation of transgenic bacteria that have received the appropriate gene from human, cow, or pig.

a. The manufacture of antibiotics

When micro-organisms are used for the production of antibiotics, it is not their fermentation products that are wanted, but complex organic compounds, called **antibiotics**, that they synthesise. Most of the antibiotics we use come from bacteria or fungi that live in the soil. The function of the antibiotics in this situation is not clear. One theory suggests that the chemicals help to suppress competition for limited food resources, but the evidence does not support this theory.One of the most prolific sources of antibiotics is *Actinomycetes*. These are filamentous bacteria that resemble microscopic mould fungi. The actinomycete *Streptomyces* produces the antibiotic **streptomycin**.

Perhaps the best known antibiotic is **penicillin**, which is produced by the mould fungus *Penicillium* and was discovered by Sir Alexander Fleming in 1928. Penicillin is still an important antibiotic but it is produced by mutant forms of a different species of *Penicillium* from that studied by Fleming. The different mutant forms of the fungus produce different types of penicillin. The penicillin types are chemically altered in the laboratory to make them more effective and to 'tailor' them for use with different diseases. 'Ampicillin', 'methicillin' and 'oxacillin' are examples.

Antibiotics attack bacteria in a variety of ways. Some of them disrupt the production of the cell wall and so prevent the bacteria from reproducing, or even cause them to burst open; some interfere with protein synthesis and thus arrest bacterial growth. Those that stop bacteria from reproducing are said to be bacteriostatic; those that kill the bacteria are bacteriocidal. Animal cells do not have cell walls, and the cell structures involved in protein production are different. Consequently, antibiotics do not damage human cells although they may produce some side-effects such as allergic reactions

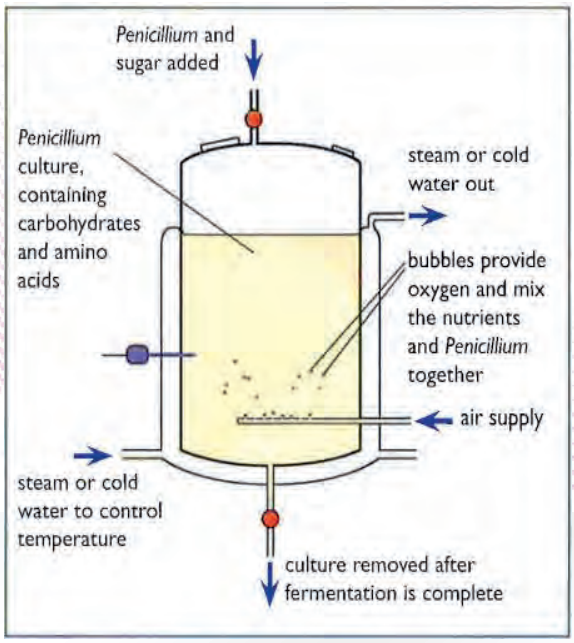


Figure 1.8. A fermenter used for producing penicilli

Activity 1.5.

- What are biosensors?
- Where do we apply biosensors?

Some vaccines are also adaptable to mass production through fermentation. Vaccines for *Bordetella pertussis, Salmonella typhi, Vibrio cholerae,* and *Mycobacterium tuberculosis* are produced in large batch cultures. *Corynebacterium diphtheriae* and *Clostridium tetani* are propagated for the synthesis of their toxins, from which toxoids for the DT vaccines are prepared.

b. Biosensors

A rapidly developing area of biotechnology, arousing intense international scientific interest, is that of **biosensor** production. In this field of bioelectronics, living microorganisms (or their enzymes or organelles) are linked with electrodes, and biological reactions are converted into electrical currents by these biosensors. Biosensors are being developed to measure specific components in beer, to monitor pollutants, and to detect flavor compounds in food. It is possible to measure the concentration of substances from many different environments. Applications include the detection of glucose, acetic acid, glutamic acid, ethanol, and biochemical oxygen

Activity 1.6.

- Where do we apply forensic science?
- Why is forensic science more reliable than other types of investigative approaches?
- What tools are used in forensic science?

demand. In addition, the application of biosensors to measure cephalosporin, nicotinic acid, and several B vitamins has been described. Recently biosensors have been developed using immunochemical-based detection system. These new biosensors will detect pathogens, herbicides, toxins, proteins, and DNA. Many of these biosensors are based on the use of a streptavidin-biotin recognition system.

One of the most interesting recent developments using these approaches is a handheld aflatoxin detection system for use in monitoring food quality. This automated unit, based on a new column-based immunoaffinity fluorometric procedure, can be used for 100 measurements before being recharged. The unit can detect from 0.1 to 50 ppb of aflatoxins in a 1.0 ml sample in less than 2 min. Aflatoxins. Rapid advances are being

made in all areas of biosensor technology. These include major improvements in the stability and durability of these units, which are being made more portable and sensitive. Microorganisms and metabolites such as glucose can be measured, thus meeting critical needs in modern medicine.

c). Forensic Science

Forensic biologists inspect crime scenes to examine potential sources of evidence using blood, saliva, and hair, and then they analyze the specimens in a laboratory, focusing on DNA analysis (Figure1.5). Additionally, fingerprints are also important tools to investigate crime and determine the paternity case of a child. This is because each individual has unique fingerprints that do not change throughout life. Based on their investigations, forensic biologists write up their findings in technical reports and are called upon to testify in court. Finally, this data is used to investigate the related transgression, and then these facts are put forward in the court that‘s quite helpful iin order to castigate the criminal. These days 'bioinformatics is widely acceptable in the field of forensic science because, with the help of computational tools, it has become quite easer and reliable to gather evidence regarding a particular crime scene.

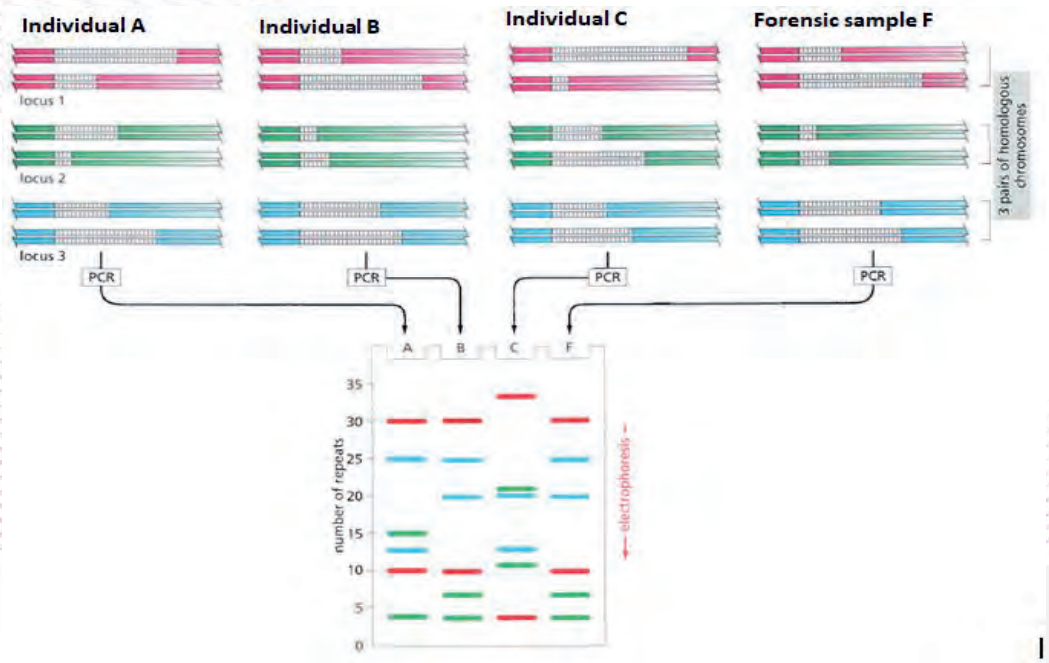


Figure 1.9. PCR as forensic science tools

Activity 1.7. Group work

Make a group and discuss the role of biological knowledge in forensic science.

When examining the variability at 5-10 different Variable Number of Tandem Repeat (VNTR) loci, the odds that two random individuals would share the same genetic pattern by chance can be approximatel1y 1 in 10 billion. In the case shown here, individuals A and C can be eliminated from further enquiries whereas individual B remains a clear suspect for committing the crime. A similar approach is now routinely used for paternity testing. The gel electrophoresis results of two-suspected paternity tests.

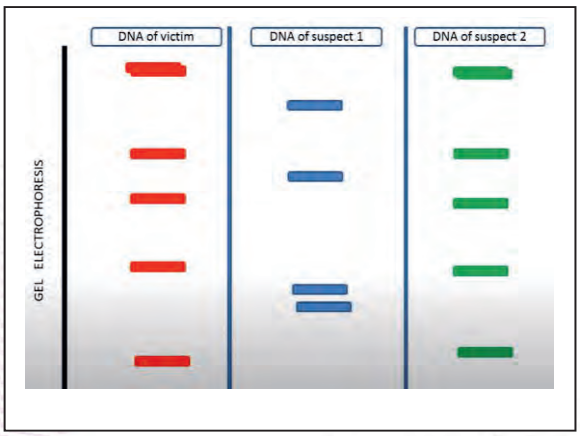


Figure 1.10. PCR in forensic application. Therefore, the suspected person (DNA of suspected 2) is the father of the baby (victim).

V). Applications in biomining

1). Microbiological mining

As the availability of mineral-rich ores decreases, methods are needed to extract minerals from less concentrated sources. This need spawned the new discipline known as biohydrometallurgy, the use of microbes to extract metals from ores. Copper and other metals originally were thought to be leached from the wastes of ore crushing as a result of an inorganic chemical reaction such as those reactions used to extract metals from ores.

It was then discovered that this leaching is due to the action of *Thiobacillus ferrooxidans*.

1.8. Activity

1. Describe how biofuel is produced?
2. Distinguish between biodegradable and non-biodegrdable substances.
3. Explain the importance of microorganisms in wastewater

This chemolithotrophic acidophilic bacterium lives by oxidizing the sulfur that binds copper, zinc, lead, and uranium into their respective sulfide minerals, with a resultant release of the pure metal. Copper in low-grade ores is often present as copper sulfide. When acidic water is sprayed on such ore, *T. ferrooxidans*

obtains energy as it uses oxygen from the atmosphere to oxidiz

the sulfur atoms in sulfide ores to sulfate. The bacterium doesn't use the copper; it merely converts it to a water-soluble form that can be retrieved and used by humans. Other minerals also can be degraded by microbes, *T. ferrooxidans* releases iron from iron sulfide by the same process. Combinations of *T. ferrooxidans* and a similar organism, *T. thiooxidans*, degrade some copper and iron ores more rapidly than either one does alone. Another combination of organisms, *Leptospirillum ferrooxidans* and *T. organoparus,* degrades pyrite (FeS2) and chalcopyrite (CuFeS2), although neither organism can degrade the minerals alone. Other bacteria can be used to mine uranium, and bacteria may eventually be used to remove arsenic, lead, zinc, cobalt, and gold. However, of late, fewer mining companies are actually using microbes in their processing. **(Vi).**

Vi. Application in the Environment

A). Solid waste treatment: composting and landfill

Most of it ends up in landfill sites- huge holes in the ground where refuse is deposited to prevent it being a hazard. The non-biodegradable components (metals, plastics, rubble, etc.) remain there more or less indefinitely; however, over a period of time biodegradable material (food waste, textiles, paper, etc.) undergoes a decomposition process. The rate at which this happens is dependent on the nature of the waste and the conditions of the landfill, but can take several decades. Aerobic processes give way to anaerobic ones and a significant result of the latter is the generation of methane. Modern landfill sites incorporate systems that remove this to prevent it being a fire/explosion hazard, and may put it to good use as a fuel source. Many householders separate organic waste items such as vegetable peelings and grass cuttings and use them to make *compost*. This practice, apart from providing a useful gardening supplement, also substantially reduces the volume of material that has to be disposed of by other means.

Self-questioning

- What are the three stages of wastewater treatment?
- Why are they important?

Fungi and bacteria, particularly actinomycetes, break down the organic

matter to produce CO2, water and humus, a relatively stable organic end product. Compost is not really a fertiliser, since its nitrogen content is not high, but it nevertheless provides nutrients to a soil and generally helps to improve its condition. Composting is carried out on a large scale by local authorities using the waste generated in municipal parks and gardens.

B). Wastewater treatment

The aim of wastewater treatment is the removal of undesirable substances and hazardous microorganisms in order that the water may safely enter a watercourse such as a river or stream. Further purification procedures are required before it can be used as drinking water. Wastewater treatment is fundamental to any developed society, and greatly reduces the incidence of waterborne diseases such as cholera. Wastewater may come from domestic or commercial sources; highly toxic industrial effluents may require pretreatment before entering a water treatment system. *Sewage* is the term used to describe liquid wastes that contain faecal matter (human or animal).

The effectiveness of the treatment process is judged chiefly by the reduction of the wastewater's *biochemical oxygen demand* (BOD). This is a measure of the amount of oxygen needed by microorganisms to oxidise its organic content. A high BOD leads to the removal of oxygen from water, a certain indicator of pollution.

Wastewater treatment usually occurs in stages, the first of which (primary treatment) is purely physical, and involves the removal of floating objects followed by sedimentation, a process that removes up to one-third of the BOD value.

Secondary treatment involves microbial oxidation, leading to a substantial further reduction in BOD. This may take one of two forms, both of which are aerobic, the traditional *trickling filter* and the more recent *activated sludge* process (Figure 1.7.). In the former, the wastewater is passed slowly over beds of stones or pieces of moulded plastic. These develop a biofilm comprising bacteria, protozoans, fungi and algae, and the resulting treated water has its BOD reduced by some 80–85%. Activated sludge facilities achieve an even higher degree of BOD reduction. Here the wastewater is aerated in tanks that have been seeded with a mixed microbial sludge. The main component of this is the bacterium *Zoogloea,* which secretes slime, forming aggregates called *flocs*, around which other microorganisms such as protozoans attach. Some of the

water's organic content is not immediately oxidised, but becomes incorporated into the flocs. After a few hours' residence in the tank, the sludge is allowed to settle out, and the treated water passes out of the system. Before being discharged to a watercourse, it is treated with chlorine to remove any pathogenic microorganisms that may remain. The principal operating problem encountered with activated sludge is that of *bulking*. This is caused by filamentous bacteria such as *Sphaerotilus natans*; it results in the sludge not settling properly and consequently passing out with the treated water.

Both secondary treatment processes result in some surplus sludge, which undergoes anaerobic digestion, resulting in the production of methane and CO2. The methane can be used as a fuel to power the plant, and any remaining sludge is dewatered and used as a soil conditioner. Care must be taken in this context, however, that the sludge does not contain toxic heavy metals.

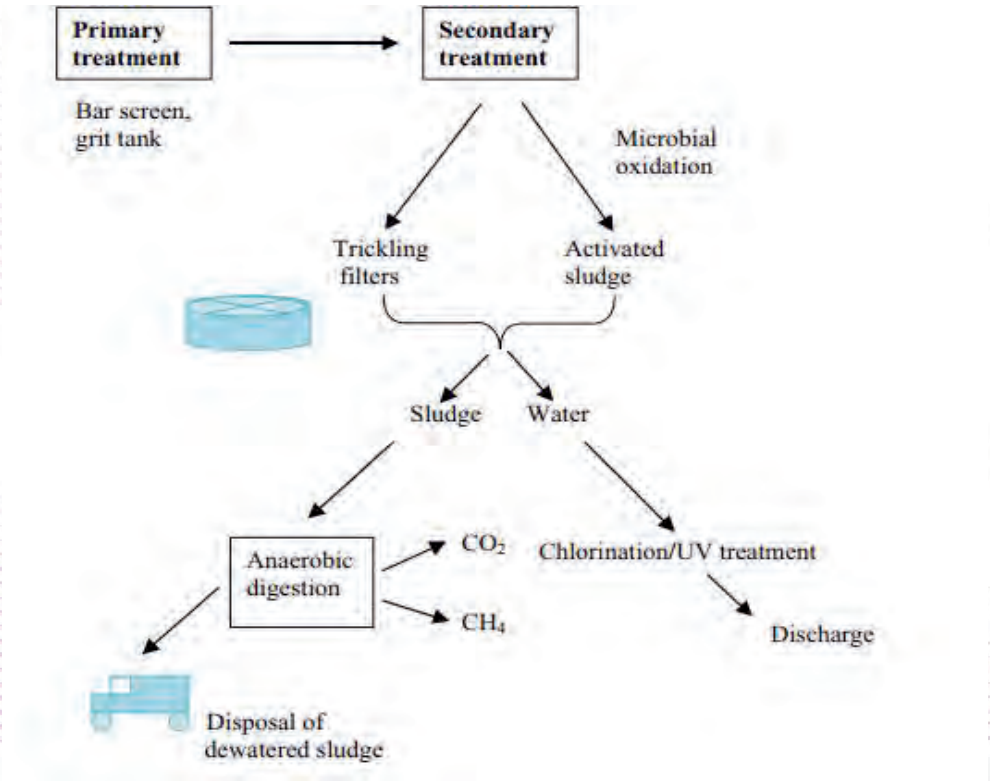


Figure 1.11. The role of microoorganisms in wastewater treatment

C). Bioremediation

Bioremediation is the use of living organisms or their products for the detoxification and degradation of environmental pollutants. Today many

pollutants are degraded with the help of saprophytic microbes; this process is also known as **biodegradation.** Genetically engineered bacterias are used to clean up pollutants from the environment. The engineered bacteria metabolically breakdown toxic pollutants into harmless compounds. Mercury resistant bacteria process metallic mercury (which damages the nervous system) into a nontoxic compound.

During bioremediation via microorganisms, enzymes produced by a microorganism modify a toxic pollutant by altering or transforming its structure. This event is called **biotransformation.** In many cases, biotransformation results in **biodegradation,** in which the toxic pollutant is degraded, were yielding less complex, nontoxic metabolites. Alternatively, biotransformation without biodegradation can also occur. For example, toxic heavy metals can often be rendered less toxic by oxidation or reduction reactions carried out by microorganisms.

D). Biofuels

The need to become independent of fossil fuels is driven by both political and environmental concerns. This has accelerated interest in and use of biofuels - fuel (chiefly ethanol) that is obtained by the fermentation of plant material. While corn is currently the substrate of choice, the use of crop residues could significantly boost biofuel yields. Crop residues are the plant material that is usually left in the field after harvest, and it consists of cellulose and hemicellulose. These polysaccharides are polymers of five different hexoses and pentose: glucose, xylose, mannose, galactose, and arabinose. While no microorganism naturally ferments all five sugars, a *Saccharomyces cerevisiae* strain has been engineered to ferment xylose and an *E. coli* strain that expresses *Zymomonas mobilis* genes is able to ferment all these sugars.

Another area of research focuses on degrading the cellulose and hemicellulose to release these monomers. This is commonly done by heating the plant material and treating it with acid, which is both expensive and corrosive. Work to harvest cellulase- and hemicellulase-producing fungi as well as bioprospecting for enzymes from thermoacidophiles are ongoing in an effort to replace the harsh thermochemical approach with a biological treatment.

E). Biogas production

Biogas is produced by bacteria and archaeans from organic matter in fermenters. Biogas is a combustible gas produced from the anaerobic breakdown of organic matter such as manure, waste plant matter from crops and household organic waste by the activities of the microorganisms. Depending on the construction of the fermenter, biogas

is mostly methane with some carbon dioxide, though other gases may be present.

Three different communities of anaerobic microbes are required. The first group converts the raw organic waste into a mixture of organic acids, alcohol, hydrogen and carbon dioxide. The second group use the organic acids and alcohol from the first stage to produce acetate, carbon dioxide and hydrogen. These first two communities are Eubacteria. The last group are Archaea called methanogens. The methanogens produce methane by one of the following two reactions:

$CO_2 + 4H_2 \rightarrow CH_4 + 2H_2O$
(reduction of carbon dioxide to methane)

$CH_3COOH \rightarrow CH_4 + CO_2$
(splitting ethanoic acid to form methane and carbon dioxide)

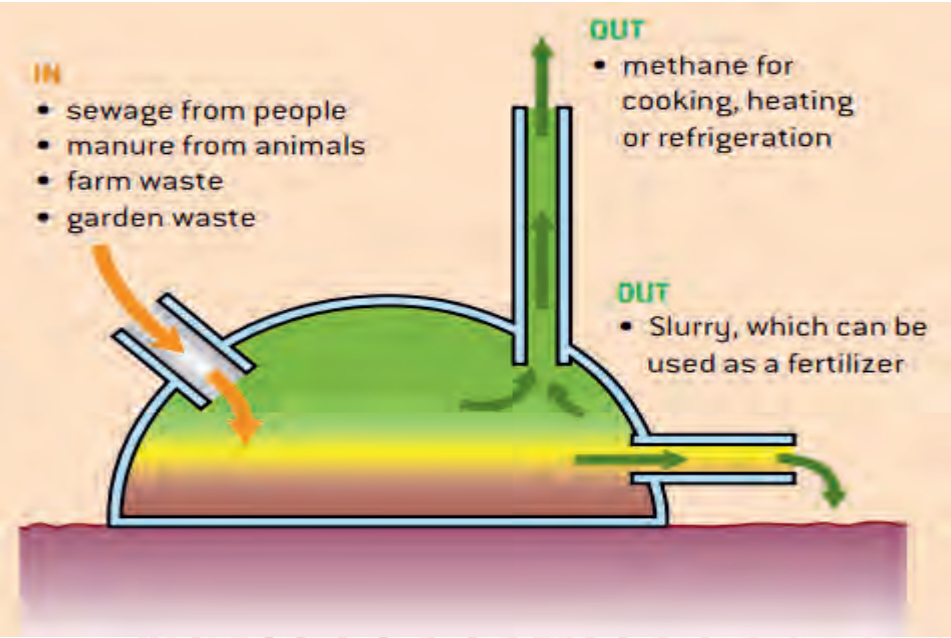


Figure 1.12. Methane generator. Conditions inside must be anaerobic

Advantages of biogas

1. Biogas is a fuel used to cook food, and light lamps.
2. Slurry left after biogas production forms a soil conditioner (manure).
3. Biogas is much cheaper than Liquefied Petroleum Gas for home use.

C) Composting

Composting is an aerobic microbial driven process that converts solid organic wastes into a stable, sanitary, humus-like material that has been considerably reduced in bulk and can be safely returned to the environment. It is, in effect, a low-moisture, solid substrate fermentation process as previously discussed. To be totally effective, it should only use as substrates readily decomposable solid

organic waste. In large-scale operations using largely domestic solid organic wastes, the final product is mostly used for soil improvement, but in more specialised operations using specific organic raw substrates (straw, animal manures, etc.), the final product can become the substrate for the worldwide commercial production of the mushroom *Agaricus bisporus*.

Composting has only recently become a serious waste management technology, and both theoretical and practical development of the technology is still in its infancy. The primary aim of a composting operation is to obtain, in a limited time within limited compost, final compost with a desired product quality. A composting plant must function under environmentally safe conditions.

Composting is carried out in a packed bed of solid organic particles in which the indigenous microbes will grow and reproduce. Free access to air is an essential requirement. The starting materials are arranged in static piles (windrows), aerated piles or covered tunnels, or in rotating bioreactors (drums or cylinders). Some form of pre-treatment of the waste may be required, such as particle size reduction by shredding or grinding. The basic biological reaction of the composting process is the oxidation of the mixed organic substrates with oxygen to produce carbon dioxide, water and other organic by-products (Figure 1.10). After the composting process is completed, the final product most often needs to be left for variable time periods to stabilize.

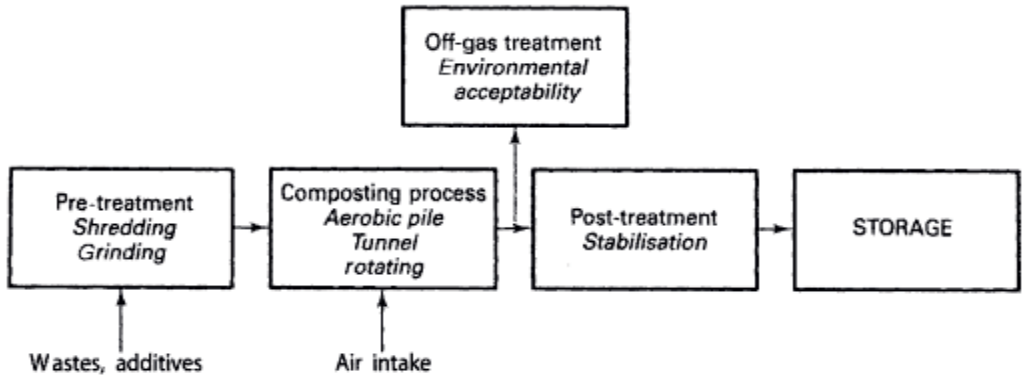


Figure 1.13. flow chart compositing plants processes

Vii. Application in Industry

A). Enzymes

Enzymes can be produced by commercial fermentation using readily available feed stocks such as corn-steep liquor or molasses. Fungi (e.g. *Aspergillus*) or bacteria (e.g. *Bacillus*) are two of the commonest organisms used to produce the enzymes. These organisms are selected because they are non-pathogenic and do not produce antibiotics. The fermentation process is similar to that described for penicillin. If the enzymes are extracellular then the liquid feedstock is filtered from the organism and the enzyme is extracted. If the enzymes are intracellular, the micro-organisms have to be filtered from the feedstock. They are then crushed and the enzymes extracted with water or other solvents.

Some commercial uses of enzymes are listed below.

- **Proteases**: In washing powders for dissolving stains from, e.g. egg, milk and blood; removing hair from animal hides; cheese manufacture; tenderising meat.
- **Lipases**: Flavors enhancer in cheese; in washing powders for removal of fatty stains.
- **Pectinases**: Clarification of fruit juices; maximizing juice extraction.
- **Amylases**: Production of glucose from starch.

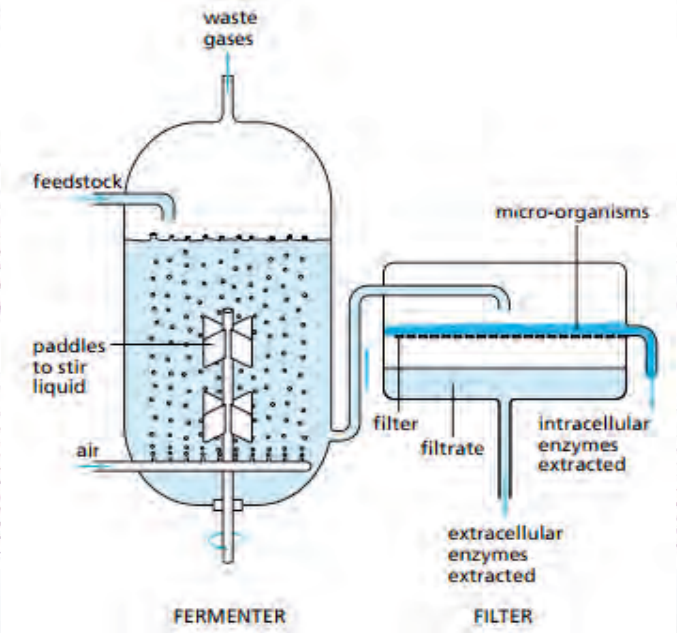


Figure 1.14. Principles of enzyme production from micro-organisms

B). Biological washing powders

The majority of commercial enzyme production involves protein-digesting

enzymes (proteases) and fat-digesting enzymes (lipases) for use in the food and textile industries. When combined in washing powders they are effective in removing stains in clothes caused by proteins, e.g. blood, egg and gravy, and fats, e.g. grease. Protein and fat molecules tend to be large and insoluble.

When they have been digested the products are small, soluble molecules, which can pass out of the cloth. Biological washing powders save energy because they can be used to wash clothes at lower temperatures, so there is no need to boil water. However, if they are put in water at higher temperatures the enzymes become denatured and they lose their effectiveness.

Viii. Applications in agriculture

A). Biopesticides

There has been a long-term interest in the use of bacteria, fungi, and viruses as **bioinsecticides** and **biopesticides**. These are defined as biological agents, such as bacteria, fungi, viruses, or their components, which can be used to kill a susceptible insect.

Bacteria: *Bacillus thuringiensis* and *Bacillus popilliae* are the two major bacteria of interest. *Bacillus thuringiensis* is used on a wide variety of vegetable and field crops, fruits, shade trees, and ornamentals. *B. popilliae* is used primarily against Japanese beetle larvae. Both bacteria are considered harmless to humans. *Pseudomonas fluorescens,* which contains the toxin-producing gene from *B. thuringiensis,* is used on maize to suppress black cutworms.

Viruses: Three major virus groups that do not appear to replicate in warm-blooded animals are used: nuclear polyhedrosis virus (NPV), granulosis virus (GV), and cytoplasmic polyhedrosis virus (CPV). These occluded viruses are more protected in the environment.

Fungi : Over 500 different fungi are associated with insects. Infection and disease occur primarily through the insect cuticle. Four major genera have been used. *Beauveria bassiana* and *Metarhizium anisopliae* are used for control of the Colorado potato beetle and the froghopper in sugarcane plantations, respectively. *Verticillium lecanii* and *Entomophthora* spp., have been associated with control of aphids in greenhouse and field environments.

B). The use of Ti plasmid as a vector

Use of tumour-inducing (Ti) plasmid of *Agrobacterium tumefaciens* to introduce glyphosate resistance into soybean crops. One way to introduce transgenes into plants is to

use *Agrobacterium tumefaciens*. This is a species of bacteria that has a plasmid, called the Ti plasmid, that causes tumours in the plants it infects.

The glyphosate resistance gene is inserted into the Ti plasmid along with an antibiotic resistance gene. The construct is then re-inserted into an *A. tumefaciens* bacterium. Plant cells are then exposed to the transgenic bacterium and cultured on a plate containing antibiotic. The only plant cells that grow are those that have taken up the plasmid. The others are killed by antibiotic.

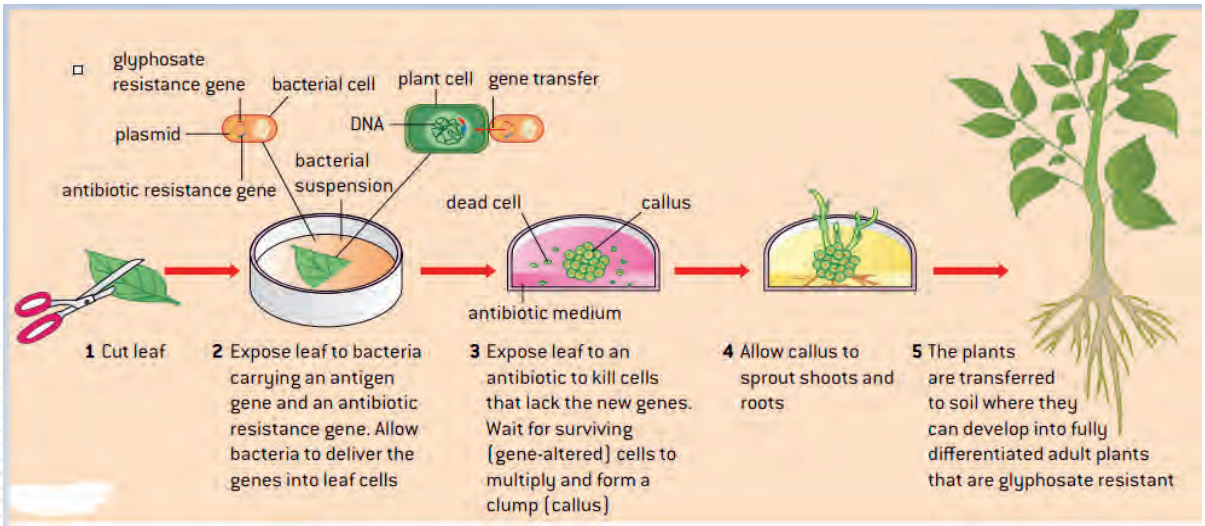


Figure 1.15. The use of Ti palmids as vector

C). Insect-resistant crops

Another important agricultural development is that of genetically modifed plants protected against attack by insect pests. Maize is protected against the corn borer, which eats the leaves of the plants and then burrows into the stalk, eating its way upwards until the plant cannot support the ear. Cotton is protected against pests such as the boll weevil (Figure 1.13). In both plants, yield is improved.

Insect-resistant tobacco also exists, and is protected against the tobacco bud worm, but as yet it has not been grown commercially. The most likely detrimental effects on the environment of growing an insect-resistant crop are:

- The evolution of resistance by the insect pests
- a damaging erect on other species of insects
- the transfer of the added gene to other species of plant.

However, less pesticide is used, reducing the risk of spray carrying to and erecting non-target species of insects in other areas. Remember also that only insects that actually

eat the crop are a erected.

Figure 1.16. a). Corn borer, b). Boll weevil

D). Pest Resistant Crops

Pest attack is one of the very common problems in a number of different crops all around the globe, these crops may include fodder crops or other crops for the purpose of getting food. One the example of such crops is BT-Cotton. The genes of *Bacillus thuringiensis* (Bt), a very common, are inserted in cotton crop in order for development of certain protein in it. The protein is very toxic to a number of different insects. With this aid of biotechnology, the developed BT-Cotton leads to a less pest attack ultimately leading to a significant more production.

E). Transgenic Animals

Although several recombinant proteins used in medicine are successfully produced in

bacteria, some proteins require a eukaryotic animal host for proper processing. For this reason, the desired genes are cloned and expressed in animals, such as sheep, goats, chickens, and mice. Animals that have been modified to express recombinant DNA are called transgenic animals. Several human proteins are expressed in the milk of transgenic sheep and goats, and some are expressed in the eggs of chickens. Mice have been used extensively for expressing and studying the effects of recombinant genes and mutations.

F). Transgenic Plants

Manipulating the DNA of plants (i.e., creating GMOs) has helped to create desirable traits, such as disease resistance, herbicide and pesticide resistance, better nutritional value, and better shelflife (Figure 1.14). Plants are the most important source of food for the human population. Farmers developed ways to select for plant varieties with desirable traits long before modern-day biotechnology practices were established.

Attention: Transgenic crops are being created that resist disease, are tolerant of herbicides and drought, and have improved nutritional quality. Plants are also being used to produce pharmaceuticals, and domesticated animals are being genetically modified to produce biologically active compounds. Plants that have received recombinant DNA from other species are called transgenic plants. Because they are not natural, transgenic plants and other GMOs are closely monitored by government agencies to ensure that they are fit for human consumption and do not endanger other plant and animal life.

Figure 1.17. Corn

Because foreign genes can spread to other species in the environment, extensive testing is required to ensure ecological stability. Staples like corn, potatoes, and tomatoes were theirst crop plants to be genetically engineered.

F). Pest resistance

Self-questioning

- What is biological warfare?
- Why the use of biological warfare is not allowed?

The bacterium, *Bacillus thuringiensis*, produces a toxin that kills caterpillars and other insect larvae. The toxin has been in use for some years as an insecticide. The gene for the toxin has been successfully introduced into some plant species using a bacterial vector. The plants produce the toxin and show increased resistance to attack by insect larvae.

G). Herbicide resistance

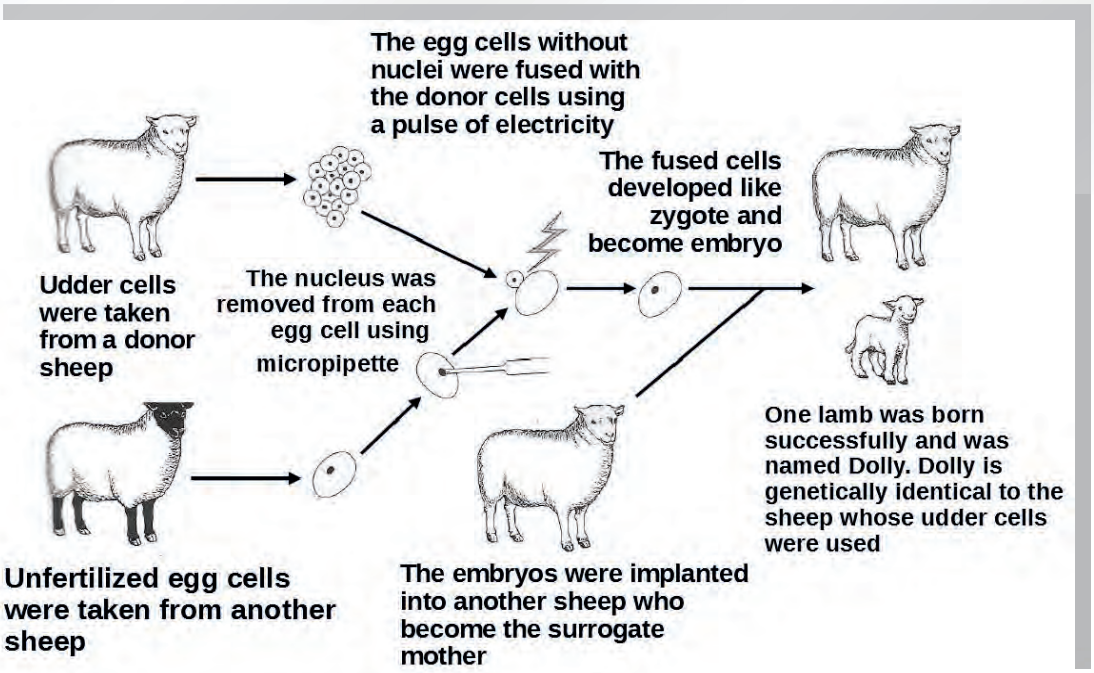
Some of the safest and most effective herbicides are those, such as glyphosate, which kill any green plant but become harmless as soon as they reach the soil. These herbicides cannot be used on crops because they kill the crop plants as well as the weeds. A gene for an enzyme that breaks down glyphosate can be introduced into a plant cell culture. This should lead to a reduced use of herbicides.

Cloning

Cloning is a method of producing identical copies of genes, cells, or organisms. The products of cloning are called a **clone**. A clone is a group of genetically identical organisms or cells produced either by asexual reproduction or artificially by cloning techniques. The main advantage of these techniques is that they can make large numbers of plants or animals, which are exact copies of a parent with desirable characteristics. Sometimes cloning is used to produce skin or other tissues needed to treat a patient.

H). Animal cloning

Animals cannot be cloned in the same way from parts of their bodies. If animal embryos are divided up at an early stage into several pieces, each piece can develop into a separate animal. However, it is hard to predict which embryos can develop into animals with desirable characteristics and should therefore be cloned. The first successful reproductive cloning of an adult with known characteristics is **Dolly** the **sheep.** Study how Dolly was cloned which is illustrated in the diagram below



Fi gure 1.18. Biotechnologically producing identical copies sheep from udder call

X. Biological warfare

Biological warfare (BW) also known as germ warfare is the use of biological toxins or infectious agents such as bacteria, viruses, and fungi with the intent to kill or incapacitate humans, animals or plants as an act of war.

Biological weapons include any microorganism (such as bacteria, viruses, or fungi) or toxin (poisonous compounds produced by microorganisms) found in nature that can be used to kill or injure people. The act of bioterrorism can range from a simple hoax to the actual use of these biological weapons, also referred to as agents. A number of nations have or are seeking to acquire biological warfare agents, and there are concerns that terrorist groups or individuals may acquire the technologies and expertise to use these destructive agents. Biological agents may be used for an isolated assassination, to cause incapacitation or death to thousands. If the environment is contaminated, a long-term threat to the population could be created.

UNIT SUMMARY

- Biotechnology is the application of scientific knowledge by industries that produce biological products like food supplements, enzymes, and drugs.
- Yeasts (Fungi), moulds (Fungi) and bacteria are important microorganisms used in industries.
- Fermentation is a process by which sugar is converted into alcohol and CO_2 by yeast.
- Fermentation by the yeast Saccharomyces yields beer and that by Lactobacillus, yields butter milk.
- Tissue culture, a method of biological research in which fragments of tissue from an animal or plant are transferred to an artificial environment in which they can continue to survive and function. The cultured tissue may consist of a single cell, a population of cells, or a whole or part of an organ.
- Genetic engineering involves the transfer of genes from one organism to an unrelated species. Genetic engineering is being used in the production of pharmaceuticals, gene therapy, and the development of transgenic plants and animals.
- Wastewater may come from domestic or commercial sources; highly toxic industrial effluents may require pretreatment before entering a water treatment system. *Sewage* is the term used to describe liquid wastes that contain faecal matter (human or animal).
- Biogas is made by the action of methanogenic bacteria on waste matter such as the faeces of humans or of cattle.
- Transgenic plants may be obtained by using the plasmid of the bacterium Agrobacterium tumefaciens.
- Transgenic animals are produced by microinjection of foreign DNA into fertilised eggs or by using retrovirus for introducing foreign DNA into early embryonic stages.
- Bioremediation refers to the use of living organisms or their products to decrease pollutants in the environment. Genetically engineered bacteria can clean up pollutants from the environment. The transformed bacteria metabolically break down toxic pollutants into harmless compounds.
- Biological warfare is the use of biological toxins or infectious agents such as bacteria, viruses, and fungi

with the intent to kill or incapacitate humans, animals or plants as an act of war.

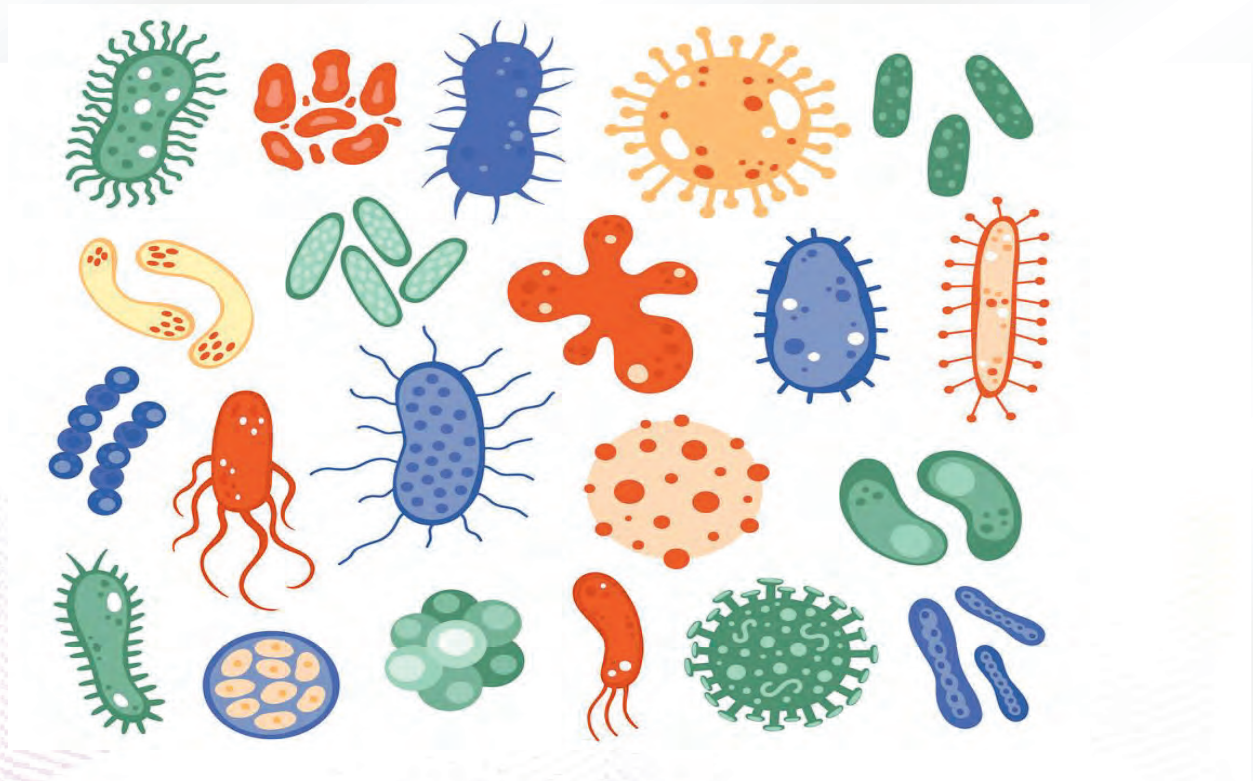
- Cloning is a technique scientists use to make exact genetic copies of living things. Genes, cells, tissues, and even whole animals can all be cloned. Some clones already exist in nature. Single-celled organisms like bacteria make exact copies of themselves each time they reproduce.

III. Review Questions

Answer the following questions

1. Define genetic engineering.
2. Differentiate between gene cloning and gene therapy.
3. List at least three different properties that have been acquired by crop plants via genetic engineering.
4. What is single-cell protein?
5. What are the different communities of anaerobic microbes involved in biogas Production?
6. Explain some medical applications of DNA technology?
7. Describe how bioremediation is helpful to humans?
8. Explain how the practical application of DNA- based biotechnology affect the human lives in many ways.
9. Why has the production of human insulin by recombinant DNA methods had significant medical advantages for diabetics?
10. How are the two fusion proteins used to make human insulin?
11. Write the benefits of biofuels.
12. Explain how can plant biotechnology be used for enhancing the nutritive qualities of Foods.
13. Explain the strategies adopted for creating transgenic plants with the following traits: (a) Disease resistance (b) Herbicide tolerance (c) Insect resistance.
14. What are the social and ethical problems associated with plant genetic engineering? How can these be addressed?
15. Explain the social, economical, and environmental implications of genetic engineering techniques.

UNIT 2: Microorganisms



Unit learning outcome

By the end of this unit, you will be able to:

- State the characteristics of microorganisms
- Describe the prevention and treatment mechanisms of diseases caused by microorganisms
- Explain different groups of microorganisms
- Explain diseases caused by microorganisms
- Discuss the importance of microorganisms in industry and the environment
- Explain diseases caused by microorganisms and viruses
- Describe prevention and treatment mechanisms of diseases caused by microorganisms

UNIT 2: MICROORGANISMS

At the end of this lesson, student will be able to:

- Categorize microorganisms based on their morphology, mode of nutrition, molecular and biochemical analysis.
- Explain the the ways of transmission and prevention of pathogenic microorganisms
- Explain the siginificances of Koch's postulates for the advancement of microbiological techniques.
- Apply the principles of microbiological techniques.
- Discuss the economic importance of microorganisms.
- Appreciate the various uses or application of microbiology in daily life.

Self-Assessment Questions;

- How do you define microorganism?
- Why is microscopic life vital for all life on earth?
- Where do microorganisms live?
- Why is it important to study microbiology?

Self-questioning

- List the types of microorganisms?
- What are the bases for microbial classifications?

Overview

Microorganisms are organisms too small to be seen clearly by the unaided eyes. *Micro* means very small—anything so small that it must be viewed with a **microscope** (an optical instrument used to observe very small objects). Therefore, **microbiology** can be defined as the study of microbes. Individual microbes can be observed only with the use of various types of microscopes. They are very small life forms so small that individual microorganisms cannot be seen without magnification. They include fungi, bacteria, algae, protozoa and viruses. Some microorganisms however, like the eukaryotic microorganisms are visible without magnification. Thus, microbiology is concerned with the study of microorganisms which include: bacteria, viruses, fungi, protozoa, algae, and helminthes (parasitic worms).

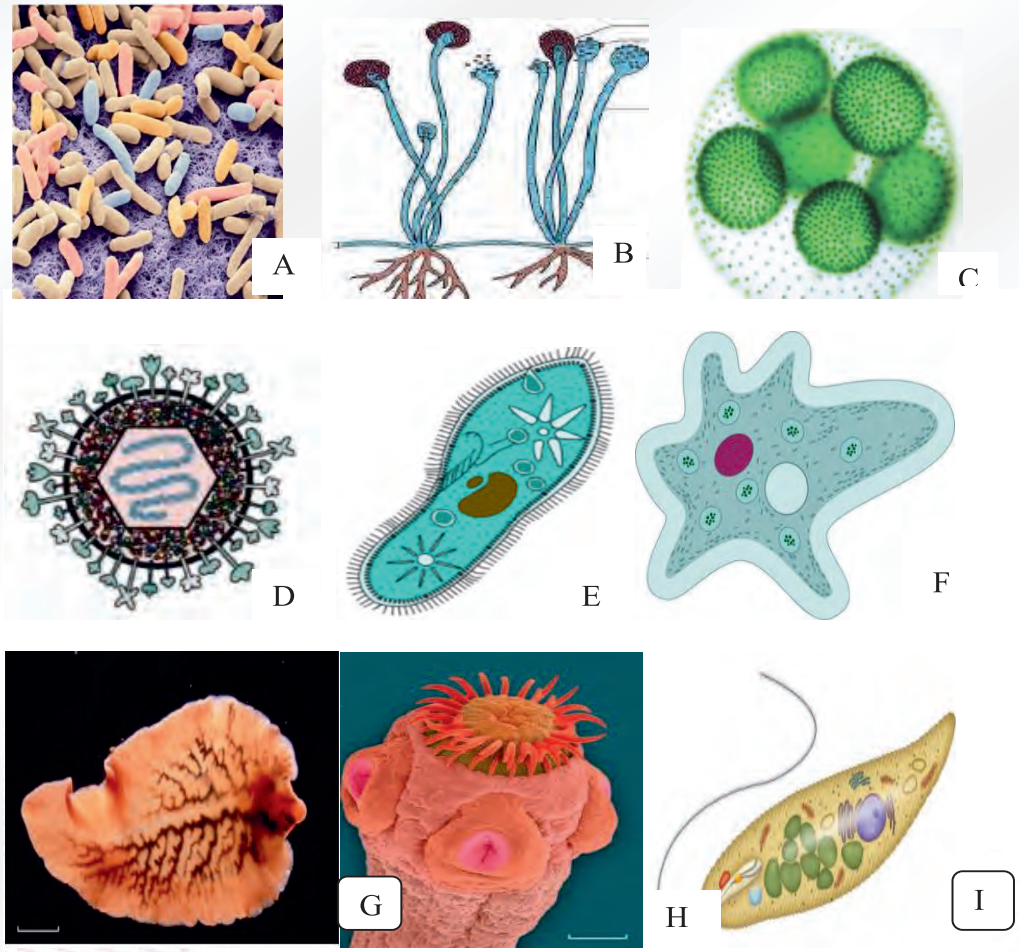


Figure 2.2. Microbial community structure: **Prokaryotes** [Bacteria (A)]; **Eukaryotes** [Fungi (B), Algae (C), Amoeba (E), Paramecium (F), Fluke (G), Tapeworm (H), Flagellates (I)] and **Acellular** [Viruses (D)]

Based on evolutionary lines, organisms are grouped into three domains: these are bacteria, archaea and eukarya (Figure 2.1).

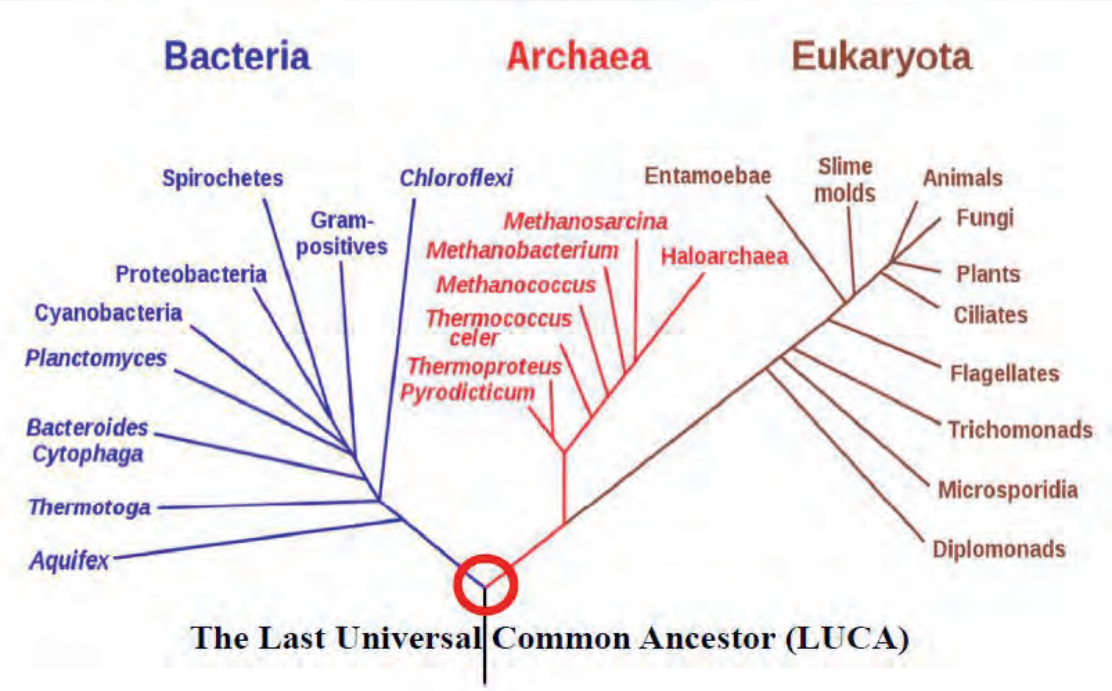


Figure 2. 1. Universal phylogenetic tree life constructed from small subunit of rRNA (SSU= **small subunit**, rRNA) gene sequence analysis

2.1. Eubacteria

At the end of this sub-section, the student will be able to:-

- describe the general features of bacteria.
- Describe the mode of nutrition in bacteria.
- explain the mechanism
- categorize bacteria based on their shapes.
- Distinguish Gram's positive and Gram's negative bacteria.
- mention some of the human diseases caused by bacteria.

Self-questioning

- What are Eubacteria and what do they do?
- Where can we get them?
- What is the difference between eukaryotes and prokaryotes?

Eubacteria (biology = definition): Literally means "**true bacteria**". Bacteria are relatively simple in structure. They are prokaryotic unicellular organisms with no nuclear membrane, mitochondria, Golgi bodies, or endoplasmic reticulum that reproduce by asexual division.

General Characteristics

- They are omnipresent i.e. present in soil, air and water.
- They are unicellular, prokaryotic microorganism.
- The cell bears a thick rigid cell wall (Peptidoglycan) outside the plasma membrane.
- They have great variation in the mode of nutrition i.e. may be autotrophic and heterotrophic. In heterotrophism mode of nutrition they may be
- parasite saprophyte or symbiotic in nature.
- They lack true chlorophyll but few photosynthetic bacteria have a special type of chlorophyll called bacteriochlorophyll.
- Lack true nucleus (lacking nuclear membrane and nucleolus).
- They lack mitochondria, Golgi apparatus, plastid and endoplasmic reticulum.
- Both DNA and RNA are present in the bacterial cell.

 Key words

- **Prokaryotes:** are a unicellular organism that lacks a nuclear membrane-enclosed nucleus.
- **Eukaryotes:** are organisms whose cells have a nucleus enclosed within a nuclear envelope.
- **Unicellular:** a unicellular organism has just one cell
- **Multicellular:** a multicellular an organism has more than one cell

 Self-questioning

- What are the Characteristics Common to all of Bacteria?

 Activity 2.1

Work in small groups on the structure and function of flagella and pili in bacteria. Make a table comparing the two different

Structure of Bacterial Cell

As bacterial cells are very minute, they are studied under electron microscope in which it reveals various structures. Some of these are external to the cell wall while other are internal to the cell wall. The brief descriptions of the readily evident structures of bacteria is as follows:

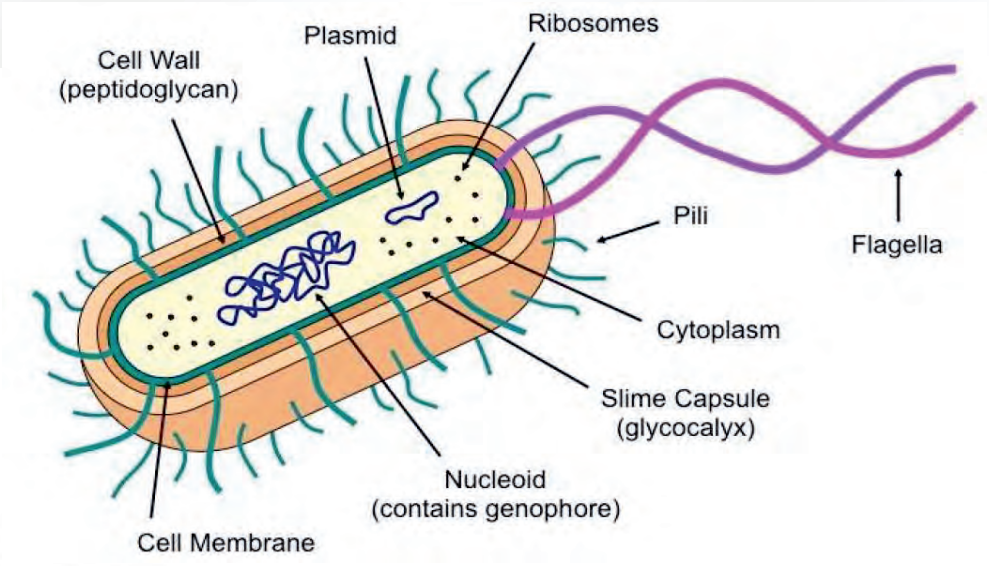
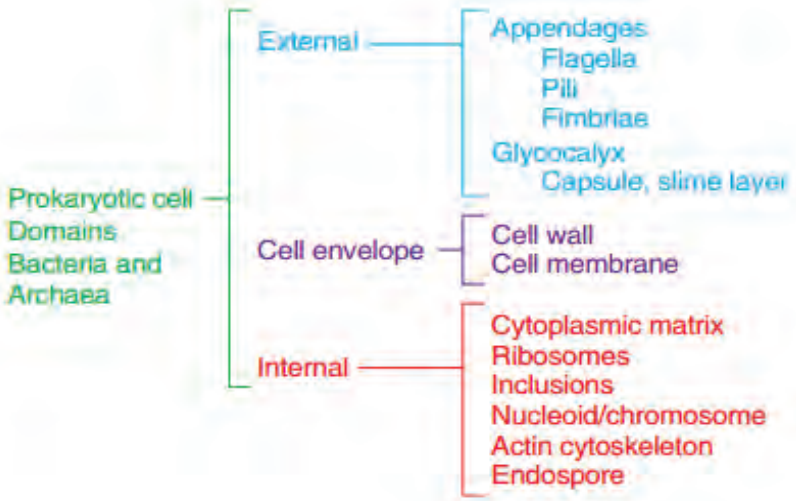


Figure 2.2. The major features of prokaryotic cell, Bacteria

The general structural plan of a prokaryotic cell can be represented with this Flowchart:



Eukaryotic microbes are an extraordinarily diverse group, including species with a wide range of life cycles, morphological specializations, and nutritional needs. Although more diseases are caused by viruses and bacteria than by microscopic eukaryotes, these eukaryotes are responsible

for some diseases of great public health importance.

Eukaryotic microbes have eucaryotic cells that have a variety of complex membranous organelles in the cytoplasmic matrix and the majority of their genetic material within membrane-delimited nuclei. Each organelle has a distinctive structure directly related to specific functions.

? Whate are the function of bacterial structure

A cytoskeleton composed of microtubules, microfilaments, and intermediate filaments helps give eukaryotic cells shape; the cytoskeleton is also involved in cell movements, intracellular transport, and reproduction. When eucaryotes reproduce, genetic material is distributed between cells by the highly organized, complex processes called mitosis and meiosis.

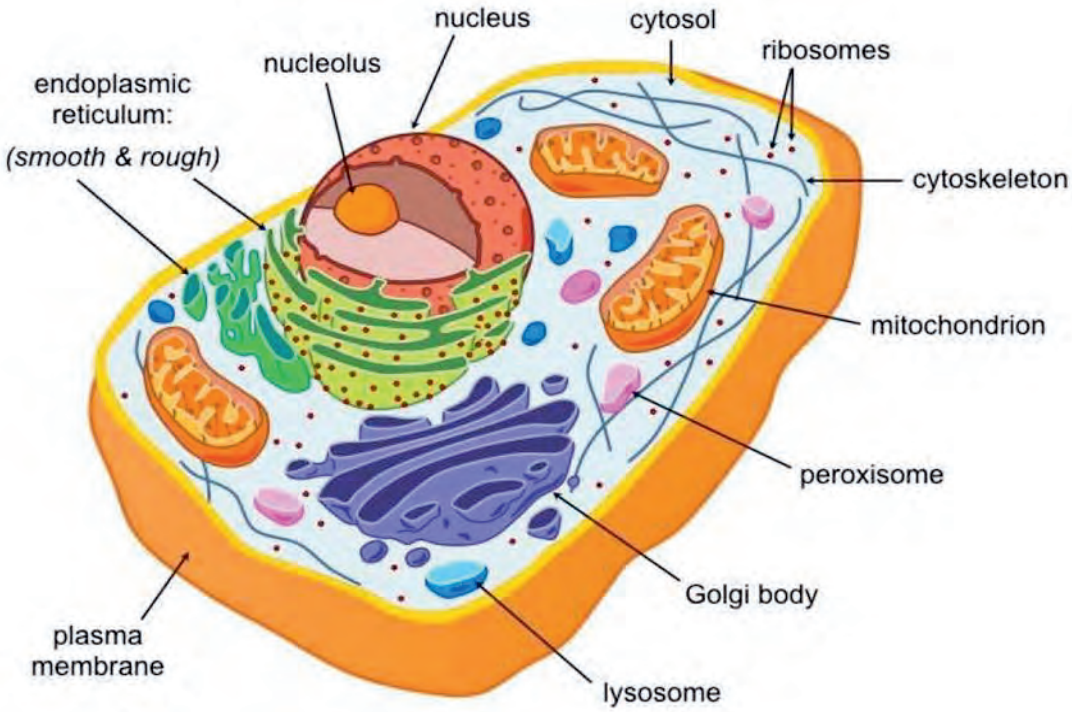


Figure 2.3. Major features of a eukaryotic cell. (Source: BioNinja)

Activity 2.2

Work in small groups and brainstorm all the differences you can think of between eukaryotic and prokaryotic cells. Make a table comparing the two different types of cells and share your ideas with the rest of the whole class.

2.1.1. Bacterial Shapes

Self-questioning

- What are the functions of bacterial structure?
- What is the difference between bacteria and archaea.
- Explain the structural difference between prokaryote and eukaryote cells?
- Can you draw the structures of prokaryote and eukaryote cells?
- What are the major differences among bacteria, archaea, and Eukaryia?

In fact, morphologically bacteria are classified based on numerous features. For example, cell shape (Figure 2.5), nature of multi cell aggregates, motility, formation of spores, and reaction to the gram stain are some of the most important features that are used to classify bacteria.

Self- questioning

- Do all bacteria have the same shapes?
- What are the three basic shapes of bacteria?
- How do the bacterial cells cluster together?

Bacterial cells can be grouped into the following three main shapes:'

- **Cocci** (singular, coccus) – spherical bacteria
- **Bacilli** (singular, bacillus) – rod-shaped bacteria
- **Spirochaetes** – spiral or corkscrew-shaped bacteria
- **Comma**-Vibrio cholera

Self-questioning

- What are the external structures of bacteria?

Activity 2.3

Streptococcus and Lactobacillus are the two well-researched types of bacteria. Carry out a library search to find out what shapes these two bacteria have, and why they are so important to us. Also, try to find two diseases caused by spiral-shaped bacteria.

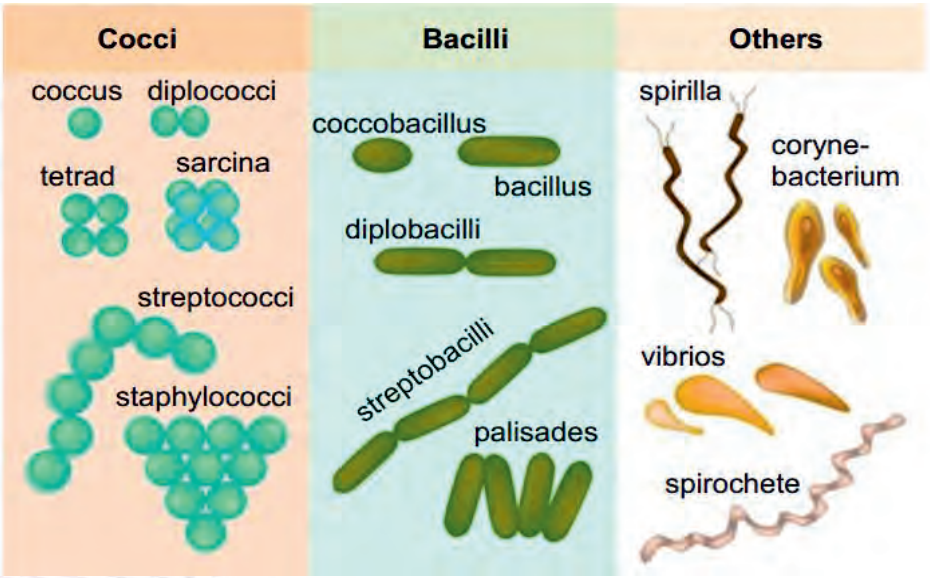


Figure 2.4. Basic bacterial shape and their clustering

Self- questioning

- Describe the following : outer membrane, periplasmic space, envelope, teichoic acid, adhesion site, lipopolysaccharide, and porin protein.
- Describe in detail the structure and composition of peptidoglycan of, gram-positive and gram-negative cell walls. Include labeled diagrams in your answer.
- Explain the role of a cell wall in protecting against lysis and illustrate how this role may be experimentally demonstrated.
- Distinguish the difference between protoplasts and spheroplasts.
- Distinguish the difference between protoplasts and spheroplasts.

Bacterial cell wall

Besides their shape bacteria can be classified based on their cell wall composition. One of these ways is whether they are retaining dyes during Gram's stain (Figure 2.6a & b). In this case, bacteria can be categorized into two:

- **Gram-positive** – Gram-positive bacteria have a distinctive purple appearance when observed under a light microscope following **Gram staining**. This is due to retention of the purple crystal violet stain in the thick peptidoglycan layer of the cell wall (Figure 2.5). Examples of Gram-positive bacteria include all staphylococci, all **streptococci** and some **listeria** species.

Gram-negative – Gram-negative bacteria **lose the crystal violet** stain (and take the color of the red counterstain) in Gram's method of staining. This is characteristic of bacteria that have a cell wall composed of a thin layer of a particular substance (called **peptidoglycan**).

Table 2.1. Comparison of Gram-Positive and Gram-Negative Cell Walls

Characteristic	Gram-Positive	Gram-Negative
Number of major layers	1	2
Chemical composition	Peptidoglycan Teichoic acid Lipoteichoic acid	Lipopolysaccharide Lipoprotein Peptidoglycan
Overall thickness	Thicker (20–80 nm)	Thinner (8–11 nm)
Outer membrane	No	Yes
Periplasmic space	Narrow	Extensive
Porin proteins	No	Yes
Permeability to molecules	More penetrable	Less penetrable

Self- questioning

- What is the purpose Gram's stain?

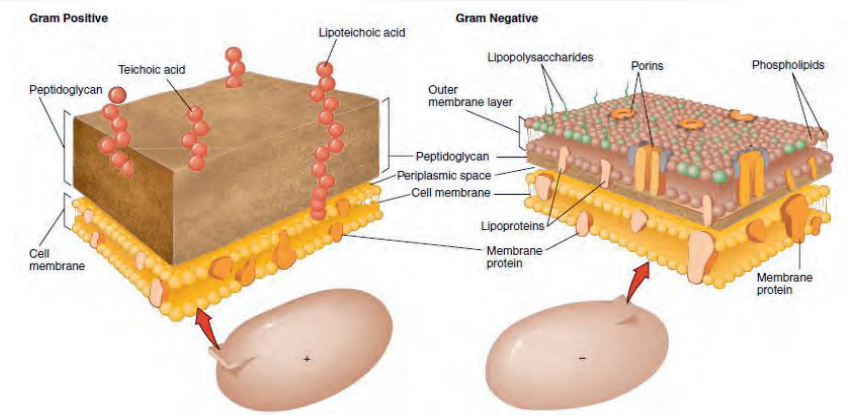


Figure 2.5. Grame positive and gram negative bacterial cell wall

The Gram staining process includes four basic steps, including:

(1) Heat fix/ attach the bacteria to the silde,

(2) . Applying a primary stain (crystal violet),

(3) . Adding a mordant (Gram's iodine),

(4) . Rapid decolorization with ethanol, acetone or a mixture of both, &

(5) . Counterstaining with safranin. Then observe the color change at each levels.

- The staining technique includes simple staining (use single dye) or differencial staining (use different dyies) (Figure 2.6)

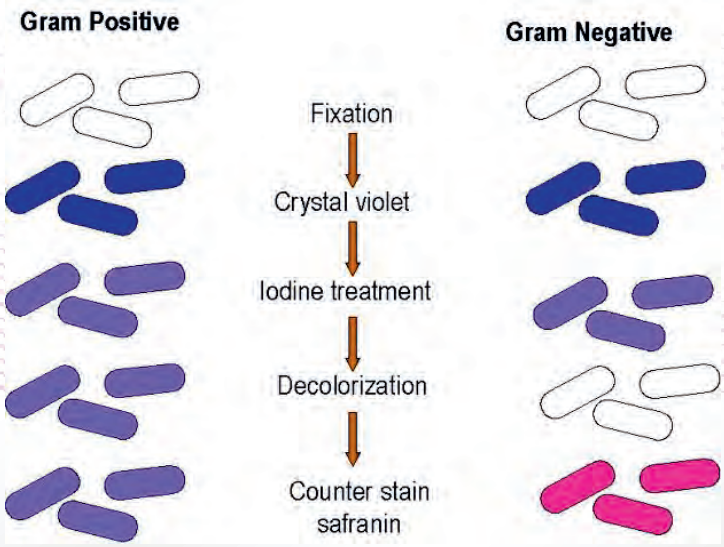


Figure 2.6. Gram staining

Key Words

Gram's staining: a test for distinguishing bacteria (named after Hans Christian Gram, who developed the technique in 1884)

Differential staining: is a staining procedure that distinguishes organisms based on their staining properties

Peptidoglycan: The rigid layer of the cell walls of Bacteria, a thin sheet composed of N-acetylglucosamine, N-acetylmuramic acid, and a few amino acids.

Endotoxin: The lipopolysaccharide portion of the cell envelope of certain gram-negative bacteria, which is toxin to human when solubilized.

Activity 2.4: Looking at bacteria in yoghurt

Per Student

- Clean glass slides and cover glasses
- Compound microscope with ocular micrometer
- Cytological stains (e.g., methylene blue, I_2KI)
- Methyl cellulose
- Immersion oil
- Cotton swabs
- Lens paper
- Lens cleaning solution
- Yoghurt
- Water
- A dropping pipettes Method
- Take a small sample of yoghurt using the pipette, and place it on a slide.
- If the sample seems too thick, dilute it with a drop of water.
- Lower a coverslip onto the yoghurt, taking care not to produce air bubbles.
- First, observe the bacteria at low power (×100) to find a good place to start looking. The diaphragm setting should be very low (small) because these bacteria are almost transparent.
- Switch to the highest power to identify the bacteria according to the shape of

cells and arrangement of the cells (pairs, clusters, chains, etc.).

- Make a drawing of the different bacteria you can see.

Question

- Why gram-positive bacterial retain crystal violate colour at the end of staining?
- Why gram-negative bacteria red at the end of staining?
- How gram-negative bacteria differ from gram positive? Discuss on their difference.

2.1.2. Nutritional types of bacteria

Bacteria have evolved many mechanisms to acquire the energy and nutrients they need for growth and reproduction. Many are autotrophs, organisms that obtain their carbon from inorganic CO_2. Autotrophs that obtain their energy from sunlight are called **photoautotrophs,** while those that harvest energy from inorganic chemicals are called **chemoautotrophs.** Other bacteria are heterotrophs, organisms that obtain at least some of their carbon from organic molecules like glucose. Heterotrophs that obtain their energy from sunlight are called **photoheterotrophs,** while those that harvest energy from organic molecules are called **chemoheterotrophs**. Sources of energy includes;

(1) light energy, and

(2) the energy derived from oxidizing organic or inorganic molecules.

Phototrophs use light as their energy source; **chemotrophs** obtain energy from the oxidation of chemical compounds (either organic or inorganic). Bacteria also have only two sources for electrons. **Lithotrophs** (i.e., "rock-eaters") use reduced inorganic substances as their electron source, whereas **organotrophs** extract electrons from reduced organic compounds.

Despite the great metabolic diversity seen in bacteria, most may be placed in one of five nutritional classes based on their primary sources of carbon, energy, and electrons. The majority of bacteria thus far studied are either photolithoautotrophic or chemoorganoheterotrophic.

Photolithoautotrophs (often called simply **photoautotrophs**) use light energy and have

CO_2 as their carbon source. Photosynthetic bacteria and cyanobacteria employ water as the electron donor and release oxygen. Other photolithoautotrophs, such as the purple and green sulfur bacteria, cannot oxidize water but extract electrons from inorganic donors such as hydrogen, hydrogen sulfde, and elemental sulfur.

Chemoorganoheterotrophs (sometimes called **chemoheterotrophs** or chemoorganotrophs) use organic compounds as sources of energy, hydrogen, electrons, and carbon.

Frequently the same organic nutrient will satisfy all these requirements. Nearly all pathogenic microorganisms are chemoorganoheterotrophs. The other nutritional types have fewer known microorganisms but are very important ecologically. Some photosynthetic bacteria (purple and green bacteria) use organic matter as their electron donor and carbon source. These **Photoorganoheterotrophs** are common inhabitants of polluted lakes and streams. Some of these bacteria also can grow as photolithoautotrophs with molecular hydrogen as an electron donor.

Chemolithoautotrophs oxidize reduced inorganic compounds such as iron, nitrogen, or sulfur molecules to derive both energy and electrons for biosynthesis. Carbon dioxide is the carbon source.

Chemolithoheterotrophs use reduced inorganic molecules as their energy and electron source but derive their carbon from organic sources. Chemolithotrophs contribute greatly to the chemical transformations of elements (e.g., the conversion
of ammonia to nitrate or sulfur to sulfate) that continually occur in ecosystems.

Table 2.2. Major Nutritional Types of Microorganisms

Nutritional Type	Carbon Source	Energy Source	Electron Source	Representative Microorganisms
Photolithoautotroph	CO_2	Light	Inorganic e^- donor	Purple and green sulfur bacteria, cyanobacteria
Photoorganoheterotroph	Organic carbon	Light	Organic e^- donor	Purple nonsulfur bacteria, green nonsulfur bacteria
Chemolithoautotroph	CO_2	Inorganic chemicals	Inorganic e^- donor	Sulfur-oxidizing bacteria, hydrogen-oxidizing bacteria, methanogens, nitrifying bacteria, iron-oxidizing bacteria
Chemolithoheterotroph	Organic carbon	Inorganic chemicals	Inorganic e^- donor	Some sulfur-oxidizing bacteria (e.g., *Beggiatoa*)
Chemoorganoheterotroph	Organic carbon	Organic chemicals often same as C source	Organic e^- donor, often same as C source	Most nonphotosynthetic microbes, including most pathogens, fungi, and many protists and archaea

2.1.3. Reproduction of bacteria

2.1.3.1. A sexual reproduction

Most bacterial organisms reproduce by an asexual process called **binary fission**, which usually occurs after a period of growth in which the cell doubles in mass. At this time, the chromosome (DNA) replicates and the two DNA molecules separate (Figure 2.7). Chromosome segregation is not well understood. Unlike eukaryotic cells,bacterial cells lack a mitotic spindle to separate replicated chromosomes. The segregation process does involve specialized chromosomal-associated proteins but there is no clear picture describing how most of these proteins work to ensure accurate chromosome segregation. In any event, cell fission at midcell involves the synthesis of a partition, or septum, that separates the mother cell into two genetically identical daughter cells.

2.1.3.2. Asexual reproduction in bacteria

In conjugation, two cells of different mating types come together, and genetic material is transferred from one to the other. In contrast to transformation and transduction, conjugation involves contact between two cells.

Conjugation has been most extensively studied in the bacterium *E. coli.* In the *E. coli* population there are donor cells, or F cells, that have DNA that can be transmitted to recipient cells, or F cells (Figure 2.8). F cells have a DNA sequence known as the F factor (F stands for fertility) that is necessary for a bacterium to serve as a donor during conjugation. The F factor, which consists of about 20 genes, can be in the form of a plasmid or it can be part of the DNA in the bacterial chromosome.

genes encode enzymes essential for transferring DNA. Certain F genes encode sex pili, long, hairlike extensions that project from the cell surface. The sex pilus recognizes and binds to the surface of an F cell, forming a cytoplasmic conjugation

bridge between the two cells. The F plasmid replicates itself, and DNA is transferred from donor to recipient bacterium through the conjugation bridge. F plasmids may also have other types of genes, including those that determine resistance to antibiotics.

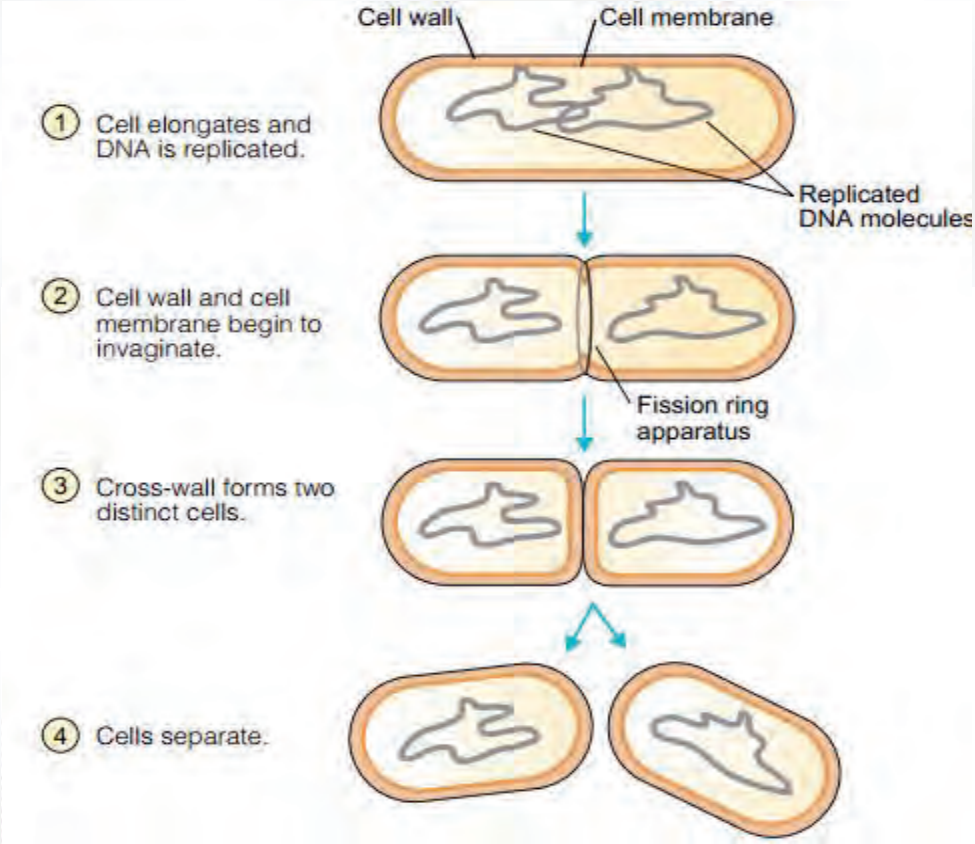


Figure 2.7. The Process of Binary Fission

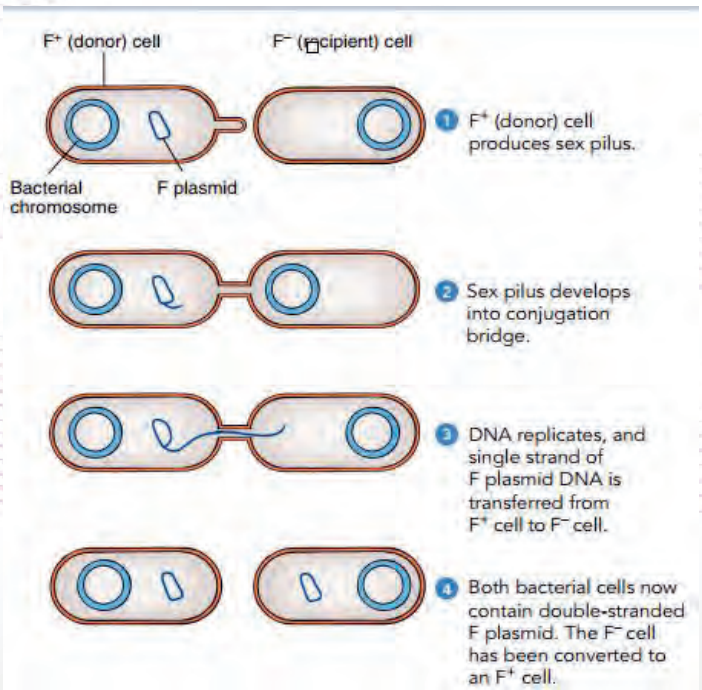


Fig 2.8. Bacterial conjugation

Table 2.3. Common bacterial diseases

Diseas	**Causative agent**	**Description of agent**	**Organs affected**	**Transmission/ vector**
Pertussis	Bordetella pertussis	Gram (-) rod	Upper resp. tract	air
Meningococcal Meningitis	Neisseria meningtidis	Gram (-) diplococcus	Upper resp. tract, meninges	air
Tuberculosis	Mycobacterium tuberculosis	Acid-fast	Lungs, bones, other organs	air
Typhoid Fever	Salmonella typhi	Gm(-) rod	Intestine, blood, gall bladder	Food, water
Cholera	Vibro cholerae	Gm(-) rod	intestine	Food, water
Tetanus	Clostridium tetani	Gm(+) spore-forming anaerobic rod	Nerves at synapse	soil
Syphilis	Treponema pallidum	Spirochete	Skin, cardiovascular organs	sexual
Gonorrhea	Neisseria gonorrhoeae	Gm(-) diplococcus	Urethra, cervix, fallopian tubes, epididymis, eyes, pharynx	sexual
Leprosy	Mycobacterium leprae	Acid-fast	Skin, bones, periphereal nerves	contact

*explain the causative agent, mode of transmission and prevention methods of chancroid, diphtheria, pneumonia, anthrax and shigellosis

2.2. Archaea

At the end of this lesson, student will be able to:

- give definition of archaea.
- describe the general features archaea.
- categorize archaea based on physiological characteristics.
- explain the beneficial aspects of archaea.

Self- questioning

Where are archaea bacteria found?

Why are archaea-bacterial and other bacterial

groups placed together?

List the general characteristics of archaea-

bacteria.

What do you think archaea-bacteria

ARCHAEA: Similar to bacteria, species in the Domain Archaea known as archaeans, are unicellular, microscopic organisms that live as producers or decomposers.

Characterisctics of Archaea

- They are prokartyotic.
- They single celled organisms.
- They lack memebrane bound nucleus and membrane bounded organelles.
- Archaea lack true peptidoglycan in their cell walls.
- Their cell membrane lipids have branched hydrocarbon chains.
- Many are found in extreme environments.

Generally three major groups of archaea are recognized: methanogens (they generate methane), extreme halophiles, and extreme thermophiles (Figure 2.9 & 2.10). These groupings are based on physiological characteristics of the organisms and therefore cannot be considered phylogenetic, or evolutionary, classifications.

The methanogens are strictly anaerobic organisms, having been isolated from such divergent anaerobic environments as waterlogged soils, lake sediments, marshes, marine sediments, and the gastrointestinal tracts of animals, including humans. As members of the anaerobic food chain, they degrade organic molecules to methane.

2. Extreme halophiles grow in highly saline environments such as the Great Salt Lake, the Dead Sea, salt evaporation ponds, and the surfaces of salt-preserved foods. Unlike the methanogens, extreme halophiles are generally obligate aerobes.

3. Extreme Thermophiles:The extreme thermophiles (hyperthermophiles) are found near volcanic vents and fissures that release sulfurous gases and other hot vapors. With optimum temperatures usually in excess of 80^0C, they may be either obligate aerobes, facultative aerobes, or obligate anaerobes.

4. Thermophilic Extreme Acidophiles: Members of two genera, *Thermoplasma* and *Picrophilus,* are notable for growing in extremely acidic, hot environments.

Keywords

- Thermophiles live at high temperatures
- Hyperthermophiles live at really high temperatures (present record is 121°C!)
- Psychrophiles (also called cryophiles) like it cold (one in the Antarctic grows best at 4°C)
- Halophiles live in very saline environments (like the Dead Sea)
- Acidophiles live at low pH (as low as pH 1 and who die at pH 7!)

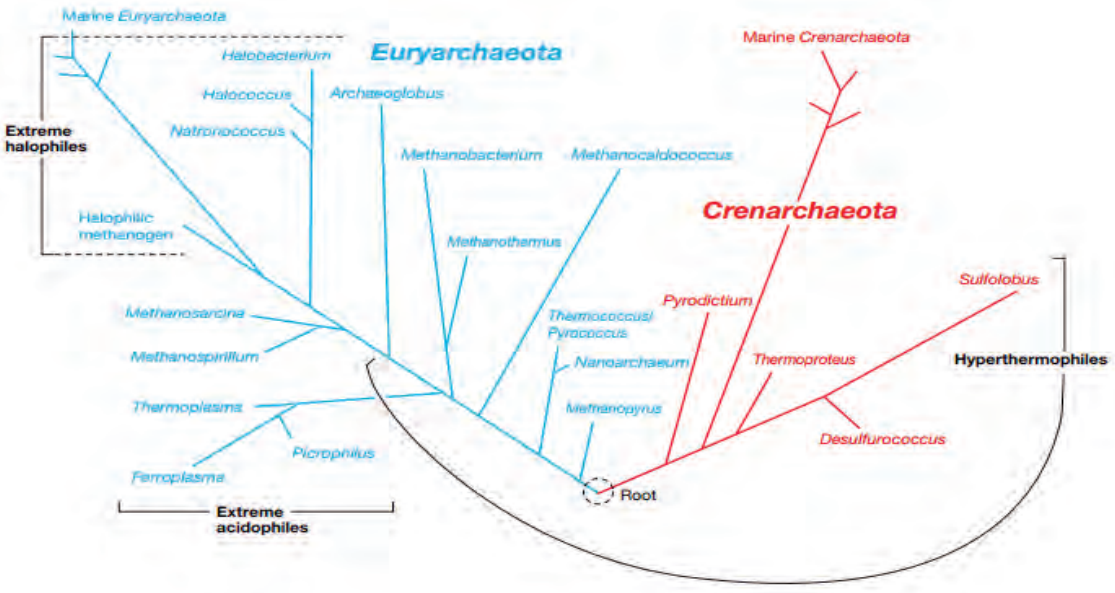


Figure 2.9. Phylogenetic tree of archaea. The tree, based on sequences of 16S ribosomal RNA genes, reveals a major evolutionary split of Archaea into two phyla, the Crenarchaeota and the Euryarchaeota.

Scientists originally identified archaea as a distinct type of prokaryotes on the basis of unique rRNA sequences. Archaea also share other common features that distinguish them from bacteria:

- Archaea lack true peptidoglycan in their cell walls.
- Their cell membrane lipids have branched hydrocarbon chains.
- The initial amino acid in their polypeptide chains, coded by the AUG start codon, is methionine (as in eukaryotes and in contrast to the N-fomylmethionine used by bacteria).

Archaea multiply by binary fission, budding, fragmentation or other mechanisms. Nutritionally they are either aerobic, facultative anaerobic or strictly anaerobic, chemolithoautotroph to organotrophs.

Figure 2.10. Diversity of Archaea

2.2.1. Beneficial aspects of Archaea

Because of their tolerance to high temperatures and relatively extreme environments, some members of the domain have already been exploited for a wide variety of commercial uses.

These Archaea become the source of enzymes that

1) are usually added to detergents in order to help it maintain its activity even at higher temperature and pH.
2) Proteases and lipases derived from alkaliphilic bacteria are being used as detergent additives to increase their stain removal ability
3) Some Archaea also bear the potential for bioremediation or help in cleaning contaminated sites.
4) The thermophilic Archaea, Thermus aquaticus, is an essential part of the development of molecular biology as a science. As a result, Archean has become the source of the enzyme harnessed as the basis for the amplification of the DNA in a technique called *Polymerase Chain Reaction* (**PCR**).

2.2.2. Physical factors that affecting microbial growths

The environments in which some microorganisms grow would kill most other microorganisms, the major physical factors which affect microbial growth are solutes and water activity, pH, temperature, oxygen level, pressure and radiation (Figure 2.11)

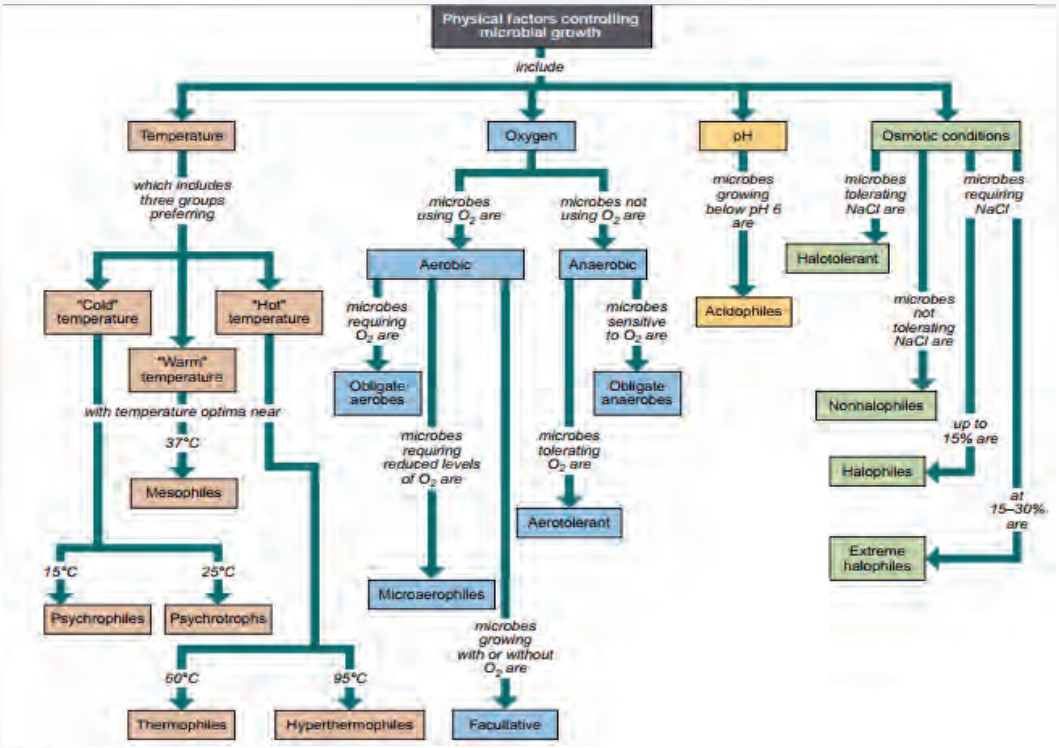


Figure 2.11. Classes of Microbes Based on Physical Factors.

After completing this section, the student will be able to:

- describe the features of fungi.
- label the structures a typical fungus.
- explain the mode of reproducuction in fungi.
- explain how fungi obtain nutrients.
- explain the economic importance of fungi.
- describe the major dvisions of fungi.
- justify why yeasts are useful to humans.
- explain the mode of transmission of fungal diseases of humans.

2.3. Fungi

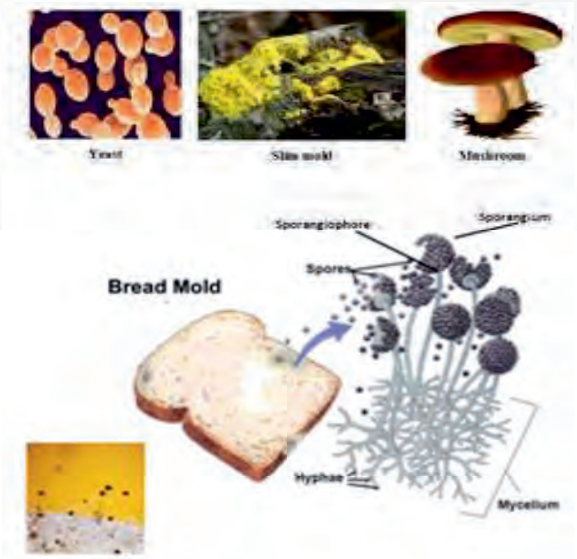


Figure 2.13. Different forms of Fungi

Microbiologists use the term **fungus** [pl., fungi; Latin *fungus,* mushroom] to describe eucaryotic organisms that are spore-bearing, have absorptive nutrition, lack chlorophyll, and reproduce sexually and asexually. Scientists who study fungi are **mycologists** [Greek *mykes,* mushroom, and *logos,* science], and the scientific discipline devoted to fungi is called **mycology.** The study of fungal toxins and their effects is called **mycotoxicology,** and the diseases caused by fungi in animals are known as **mycoses** (s., mycosis).

Self-questioning

- ? What are the general characteristics of true fungi?
- ? Do fungi have a benefit for humans? If yes, list their importance.
- ? Where do different fungal groups grow in nature? How do different fungi get their nutrients?
- ? What features of fungal species may be interpreted as adaptations to life as a saprobe, a pathogen, or a mutualistic/ symbiont? Which fungal features permit some fungal species and not others to be pathogenic on humans?
- ? What are the ecological roles of different kinds of fungi?
- ? How do different kinds of fungi, including lichenized fungi, reproduce asexually? sexually?
- ? Why are there two names for the same fungus or fungal group? Provide specific examples.

2.3.1. General Characteristics of True Fungi

1. All are eukaryotic

- Possess membrane-bound nuclei (containing chromosomes) and a range of membrane bound cytoplasmic organelles (e.g. mitochondria, vacuoles, endoplasmic reticulum).

2. Most are filamentous (Figure 2.12, & 2.13)

- Composed of individual microscopic filaments called hyphae, which

exhibit apical growth and which branch to form a network of hyphae called a mycelium (Figure 2.8).some have septate hyphae, and the other have nonsepatate (coenocytic hyphae)

3. Some are unicellular • e.g. yeasts. (Figure 2.12)

4. Protoplasm of a hypha or cell is surrounded by a rigid wall

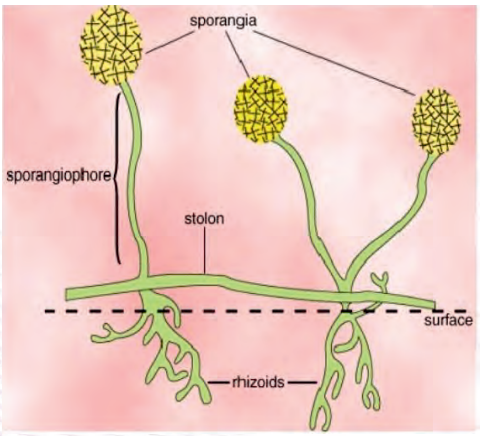


Figure 2.13. mycelium

- Composed primarily of chitin and glucans, although the walls of some species contain cellulose.

5. Many reproduce both sexually and asexually

• Both sexual and asexual reproduction often result in the production of spores.

6. Their nuclei are typically haploid and hyphal compartments are often multinucleate

• Although the Oomycota and some yeasts possess diploid nuclei.

7. All are achlorophyllous

• They lack chlorophyll pigments and are incapable of photosynthesis.

8. All are chemoheterotrophic (chemo-organotrophic)

• They utilize pre-existing organic sources of carbon in their environment and the energy from chemical reactions to synthesize the organic compounds they require for growth and energy.

9. Possess characteristic range of storage compounds

Self-questioning

? What are traditional fermented foods?
? List the Ethiopian traditional fermented foods, beverages, and condiments.
? What do you think is the role of fungi in the production of traditional fermented products?
? What is starter culture?
? How do local people preserve starter culture for a long-time use?
? Which fungal groups are commonly involved in food fermentation?

• e.g. trehalose, glycogen, sugar alcohols and lipids.

10. Nutritionally categorized into three (saprophytic, parasitic, and symbiotic).

*what are the differences between fungi and bacteria

2.3.2. Ecology of Fungi

Fungi have colonized nearly all environments on Earth, but are frequently found in cool, dark, moist places with a supply of decaying material. Fungi are saprobes that decompose organic matter. Many successful mutualistic relationships involve a fungus and another organism. Many fungi establish complex mycorrhizal associations with the roots of plants. Some ants farm fungi as a supply of food.

Lichens are a symbiotic relationship between a fungus and a photosynthetic organism, usually an algaor cyanobacterium. The photosynthetic organism provides energy derived from light and carbohydrates,while the fungus supplies minerals and protection.

- Zygomycota. Sporangial fungi, E.g. rhizopus and mucor
- Ascomycota. Ascospore producing fungi. E.g. *Saccharomyces cerviciae*
- Basidomycota. Basidia producing fungi. E.g. rusts & smuts

2.3.4. Reproduction in fungi

Sporulation is the process of spore formation. It usually occurs in structures called **fruiting bodies**, which represent the part of a fungus in which spores are formed and from which they are released. These structures may be asexual and invisible to the naked eye, or sexual structures, such as the macroscopic mushrooms..

Self-questioning

- Which funguses are common in food spoilage?
- What does a fungal disease mean?
- List at least five diseases caused by fungi?
- What are the main human diseases caused by fungi?

Some animals that consume fungi help disseminate spores over long distances.

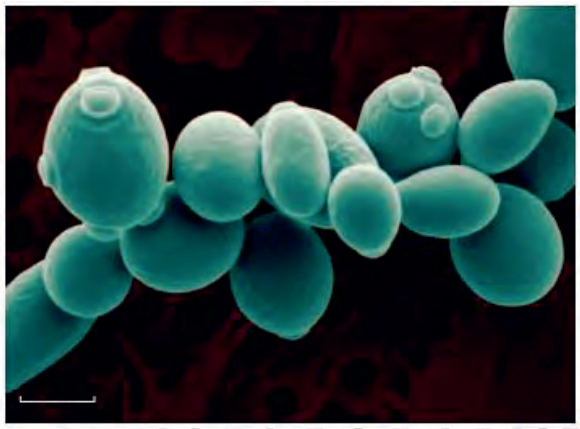
2.3.3. Classification of Fungi

Many mycologists currently recognize five major groups of fungi, although recent genomic evidence indicates that the chytrids and zygomycetes are paraphyletic.

In a group of 5-10, search on Google and discuss the fungal specie that are common to the Ethiopian traditional fermented Enjera, Kocho, Bulla, Tej, Shameta, and different condiments.

The current classifications of fungi includes:

- Chytridomycota. Zoospore producing fungi. E.g. allomyces & water molds
- Glomeromycota. E.g. mycorrhizal fungi.



A) Asexual reproduction

Asexual reproductive structures develop at the ends of specialized hyphae. As a result of mitotic divisions, thousands of spores are produced, all genetically identical.

Many asexual spores develop within sacs or vessels called sporangia (sing., sporangium; *angio* = "vessel"). Appropriately, the spores are called sporangiospores. Other fungi produce spores on supportive structures called conidiophores. These unprotected, dust-like spores are known as conidia (sing., conidium; *conidio* = "dust") (Figure 2.14). Fungal spores are extremely light and are blown about in huge numbers by wind currents. In yet other fungi, spores may form simply by fragmentation of the hyphae yielding arthrospores (*arthro* = "joint"). The fungi that cause athlete's foot multiply in this manner.

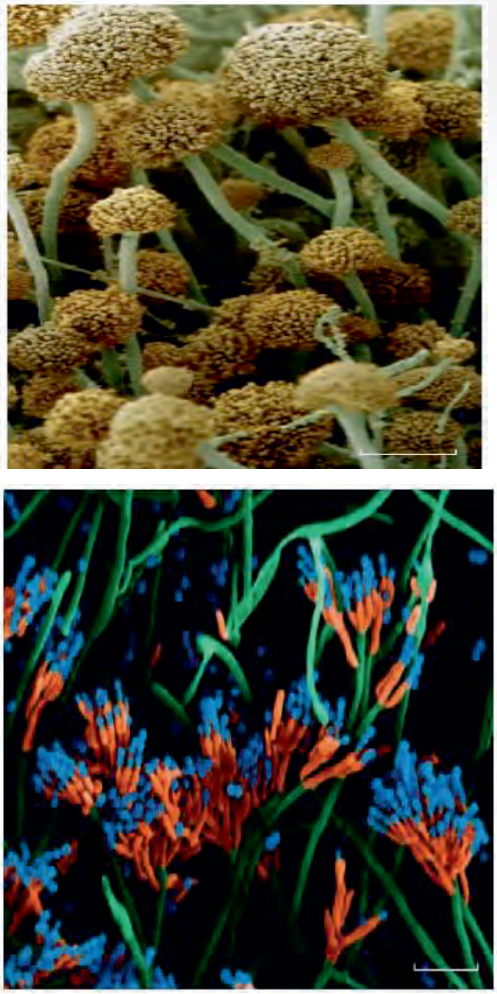


Figure 2. 14. Fungal fruiting bodies

A). Sporangia of the common bread mold *Rhizopus (B)* The conidiophores and conidia

Many yeasts reproduce asexually by **budding (Figure 2.15)**. In this process, the cell becomes swollen at one edge, and a new cell called a **blastospore**, (*blasto* = "bud") develops (buds) from the parent cell. Eventually, the spore breaks free to live independently. The parent cell can continue to produce additional blastospores.

Figure 2.15. Budding in yeast

B) Sexual reproduction

Many fungi also produce spores by sexual reproduction. In this process, opposite mating types come together and fuse (Figure 2.16). Because the nuclei are genetically different in each mating type, the fusion cell represents a heterokaryon (*hetero* = "different"; *karyo* = "nucleus"); that is, a cell with genetically dissimilar nuclei existing for some length of time in a common dikaryotic cytoplasm. Eventually the nuclei fuse and a diploid cell is formed. The chromosome number soon is halved by meiosis, returning the cell or organism to a haploid condition.

A visible fruiting body often results during sexual reproduction and it is the location of the haploid spores. Perhaps the most recognized fruiting body from which spores are produced is the mushroom.

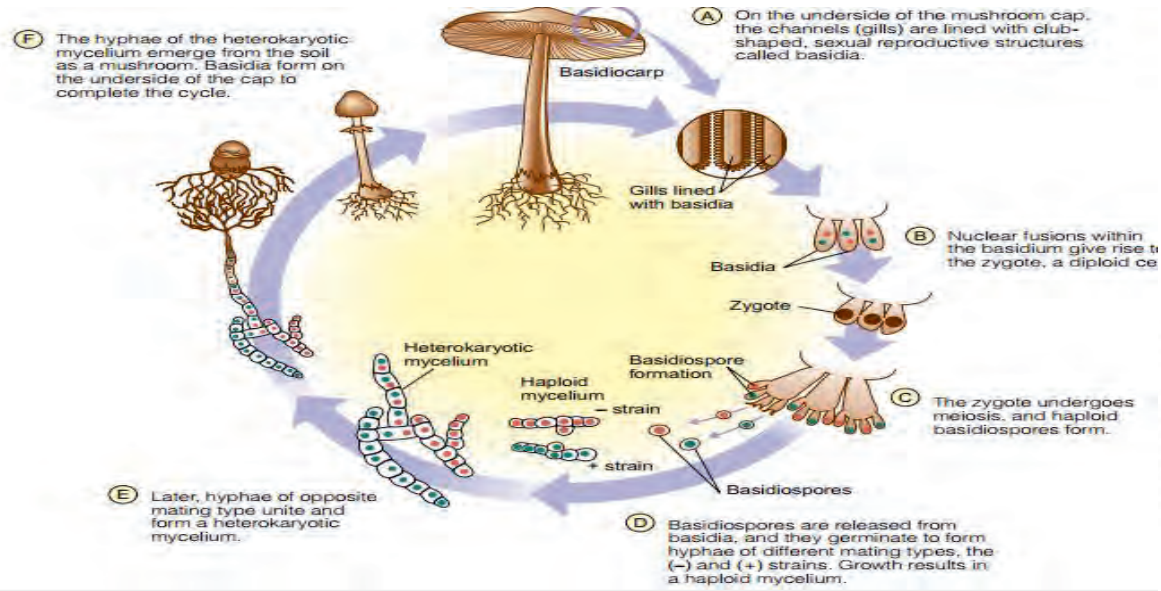


Figure 2 .16 The Sexual Reproduction Cycle of a Typical Basidiomycete.

2.3.5. Economic importance of fungi

Fungi are among the economic important microrganisms. They have both beneficial and harnmful aspects.

Beneficial aspects of fungi

1. Fungi exist either as *saprobes* or *parasites*. Their preeminent ability to break down complex organic substrates of almost every type is an important and essential activity in the recycling of carbon and other elements in the cycle of life.

2. Edible wild or domesticated varieties of mushrooms (*Basidiomycetes*) are important as food sources.

3. Fungi, especially the yeasts, are essential to many industrial processes involving fermentation. Examples include the making of bread, wine, and beer.

4. Fungi also play a major role in the preparation of some cheeses, soy sauce, and

sufu, Enjera, Tela(Farsoo), Tej(Dadhii), bulla, ETC. (Figure 2.17); and in the commercial production of many organic acids (citric, gallic) and certain drugs (ergometrine, cortisone).

5. Molds (such as *Aspergillus* species) are used in the production of citric, oxalic, gluconic and itaconic acid.

Products of fermentation yield industrial alcohol, fats and proteins. A mold (*Fusarium*) can produce within 48 hours, 12-15 grams of fat from a litre of 50% glucose solution.

6. Fungi play a major role in the manufacture of many antibiotics (penicillin, griseofulvin) and the immunosuppressive drug cyclosporin.

7. Actinomycetes and fungi are important sources of antibiotics such as penicillin, amphotericin B, adriamycin and bleomycin, etc.

8. Fungi are useful tools for studying complex eukaryotic events, such as cancer and aging within a simple cell.

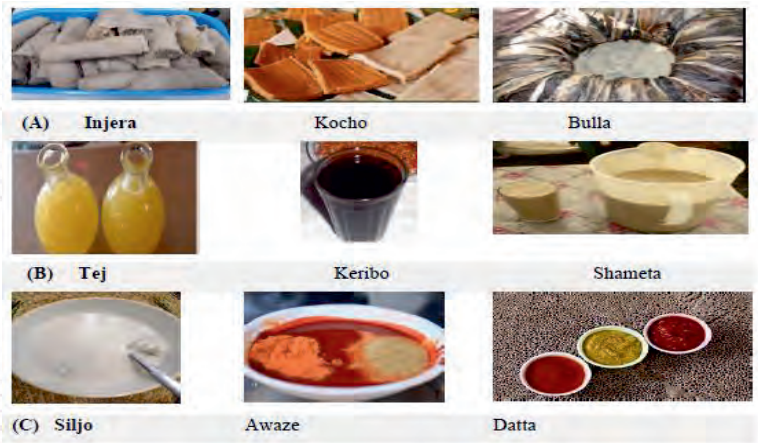


Figure 2.17. Some Ethiopian traditional fermented products prepared by using yeast for fermentations (A= staple foods; B, beverages; and C, condiments)

Harmful aspects of Fungi

1. Fungi are the major cause of plant diseases. Plants are particularly vulnerable to fungal diseases because fungi can invade leaves through their stomates. Over 5,000 species attack economically valuable crops, garden plants, and many wild plants. Fungi also cause many diseases of animals and humans.

2. Molds can cause deterioration of fabrics, leather, electrical insulation and other

manufactured goods. Extensive losses may follow failure to protect material from ravages of fungi in warm humid climates.

3. Fungi can spoil the agricultural produce, if improperly stored. These also destroy vegetables, fruits and cereals.

4. Mycotoxicoses (ingestion of toxins of fungal origin) and mycetismus (mushroom poisoning through ingestion of fungal elements).

A. Aflatoxis: Two closely related fungi, *Aspergillus flavus* and *A. parasiticus,* produce mycotoxins called **aflatoxins**. The molds are found primarily in warm, humid climates, where they contaminate agricultural products such as peanuts, grains, cereals, sweet potatoes, corn, rice, and animal feed. Aflatoxins are deposited in these foods and ingested by humans where they are thought to be carcinogenic, especially in the liver. Contaminated meat and dairy products are also sources of the toxins.

B. Ergotism is caused by *Claviceps purpurea,* an ascomycete fungus producing a powerful toxin. *C. purpurea* grows as hyphae on kernels of rye, wheat, and barley. As hyphae penetrate the plant, the fungal cells gradually consume the substance of the grain, and the dense tissue hardens into a purple body called a **sclerotium**. A group of peptide derivatives called alkaloids are produced by the sclerotium and deposited in the grain as a substance called **ergot**. Products such as bread made from rye grain may cause ergot rye disease, or ergotism.

C. **Mushroom poisoning**, or **mycetism,** can occur from mushrooms that produce mycotoxins that affect the human body.

5. Superficial Fungal infections

Superficial mycoses are fungal infections of the outermost areas of the human body: hair, fingernails, toenails, and the dead, outermost layers of the skin (the epidermis). This a complex of diseases caused by any of several species of taxonomically related flamentous fungi in the genera *Trichophyton, Epidermophyton,* and *Microsporum*.

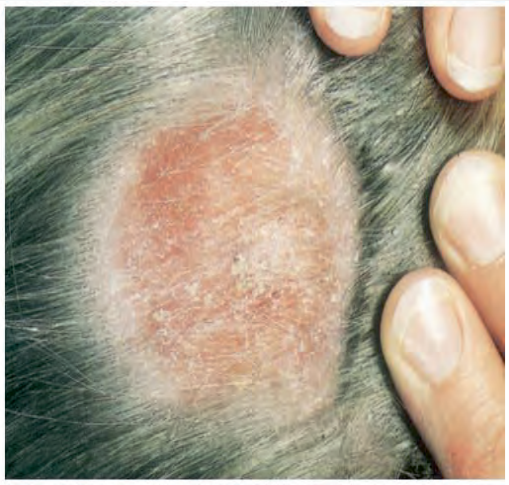
The various forms of dermatophytosis are referred to as tineas or "ringworm." Clinically, the tineas are classifed according to the anatomic site or structure affected:

1. *Tinea corporis* (ringworm): Microsporum canis and Trichophyton mentagrophytes. Affects hairless skin.
2. *Tinea pedis* (athlete's foot): *T. rubrum*, T. *mentagrophytes*, and *Epidermophyton floccosum*. Affects mainly the lower legs.
3. *Tinea capitis: T. tonsurans* and *M. canis*. the scalp, eyebrows, and eyelashes
4. *Tinea barbae: T. rubrum and T. mentagrophytes*. Beard ringworm.

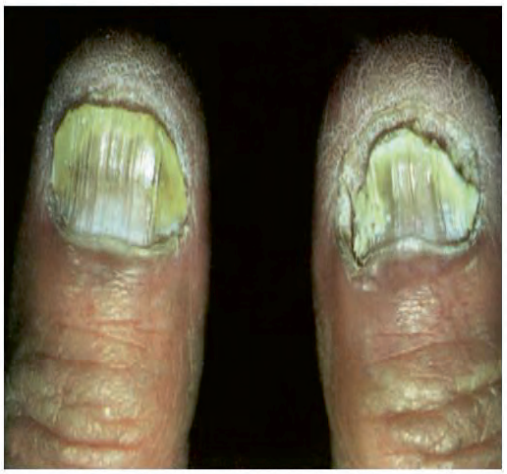
5. *Tinea unguium* (also known as **onychomycosis**).: *T. rubrum, T. mentagrophytes*, and *E. floccosum*. Affect the nails

Mode of transmission: Superficial mycoses (Dermatomycoses) are infections that are transmitted directly by human contact, animal-human contact or indirectly on inanimate objects (clothes, carpets, moisture, and dust in showers, swimming pools, wardrobes, gyms). The localization of the primary foci corresponds to the contact site. Thus feet, uncovered skin (hair, head, facial skin) are affected most frequently (Figure 2.18).

Prevention: Regular disinfection of showers and wardrobes can contribute to prevention of athlete's foot, a very frequent infection



Onychomycosis caused by *Trichophyton rubrum*



Tinea capitis caused by *Microsporum canis*

Figure 2.18. Fungal disease affecting human and plants

Table 2. 4. Summry of some fungal diseases

Diseases	Causative agent	Signs and symptoms	Transmission	Prevention and control
Dermatophytosis (tineas)	Epidermophyton Microsporum Trichophyton	Blister-like lesions	Fragments of skin on skin floors or surfaces	Keeping skin dry not sharing personal items
Candidiasis	Candida albicans	Itching, burning pains, “cheesy” discharge	sexually	Avoiding baths hot and tubs , Avoiding douches
Thrush	Candida albicans	White flecks on mucous membranes	Passage through the birth canal	Practicing good oral hygiene, limiting sugar intake
Aspergillosis	Aspergillus fumigatus	Bloody cough, chest pain, Wheezing Shortness of breath	Air borne spores	Staying away from sources of mold

2.4. Protozoa

The term protozoa [s., protozoan; Greek protos, first, and zoon, animal] has traditionally referred to chemoorganotrophic protists, and protozoology generally refers to the study of protozoa.

Characteristics of protozoa

- Unicellular microorganisms that lacks cell wall.
- They are may be free living or parasitic.
- Aerobic.
- They have true nucleus.
- They are eukaryotic cells.
- Mostly microscopic, although some are large enough to be seen with the unaided eye (Figure 2.19).
- Locomotion by pseudopodia, flagella, cilia, and direct cell movements; some sessile.
- Nutrition of all types: autotrophic (manufacturing own nutrients by photosynthesis), heterotrophic (depending on other plants or animals for food), saprozoic (using nutrients dissolved in the surrounding medium)
- Aquatic or terrestrial habitat; free-living or symbiotic mode of life
- Reproduction asexually by fission, budding, and cysts and sexually by conjugation or by syngamy (union of

After completing this section, the student will be able to:

- describe the general features of protozoa.
- describe the structures of ameaba, euglena, paramecium.
- explain how protozoans get nutrition.
- describe the modes of reproduction in protozoa.
- describe the process of conjugation in protozoa.
- list the common diseases caused by protozoans.
- explain the ways of transmission of protozoan diseases.
- explain the economic importance of on human protozoans.
- analyze the health impacts of different protozoan diseases.

Self-questioning

- Can protozoan reproduce?
- How are Amoeba, Euglena, and Paramecium reproduced?
- Draw and label the structure of Amoeba, Euglena, and Paramecium.

male and female gametes to form a zygote).

Table 2.5. Classification of protozoa

CATEGORY	MEANS OF MOVEMENT	METHOD OF ASEXUAL REPRODUCTION	METHOD OF SEXUAL REPRODUCTION	REPRESENTATIVES
Ciliates	Cilia	Transverse fission	Conjugation	*Balantidium coli, Paramecium, Stentor, Tetrahymena, Vorticella*
Amebae (amebas)	Pseudopodia (false feet)	Binary fission	When present, involves flagellated sex cells	*Amoeba, Naegleria, Entamoeba histolytica*
Flagellates	Flagella	Binary fission	None	*Chlamydomonas, Giardia lamblia, Trichomonas, Trypanosoma*
Sporozoa	Generally nonmotile except for certain sex cells	Multiple fission	Involves flagellated sex cells	*Plasmodium, Toxoplasma gondii, Cryptosporidium*

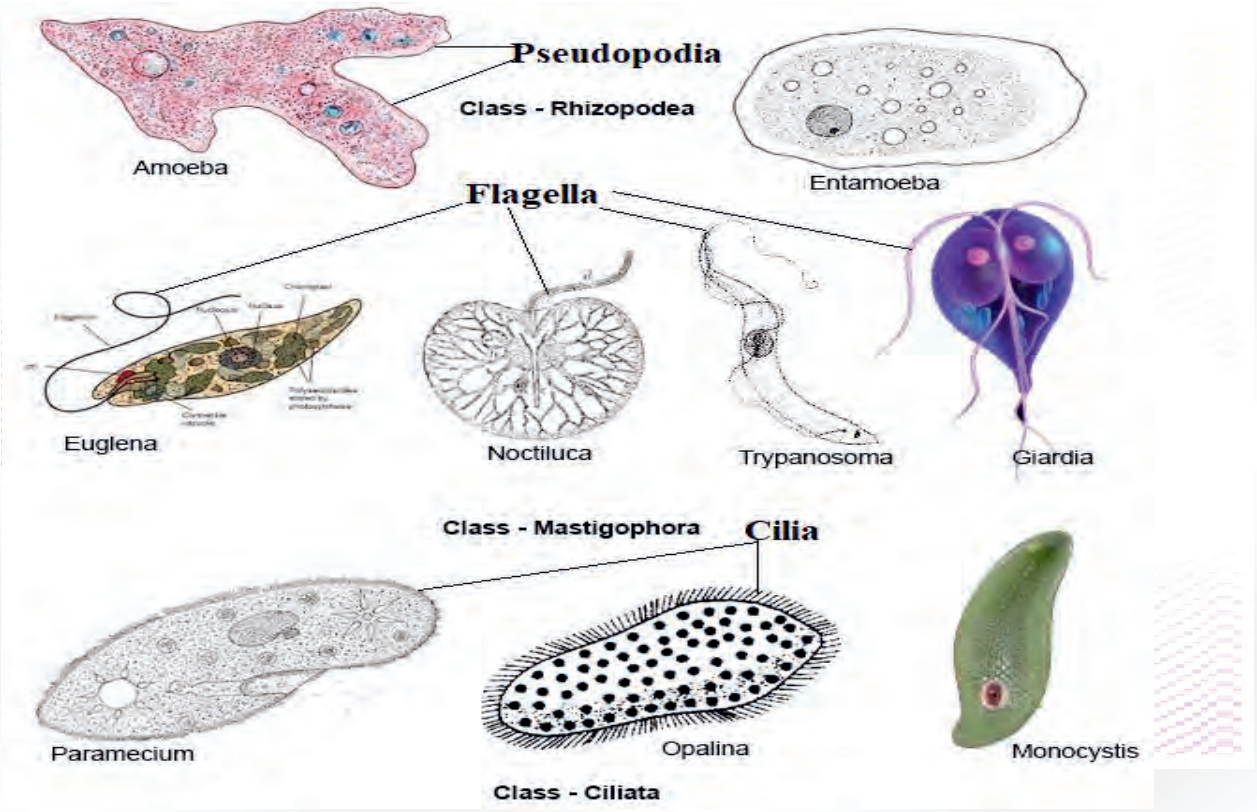


Figure 2.19. Common protozoa

Reproduction in protozoa

Most protozoa are asexual and reproduce in one of three ways. These are:

• *Fission:* Fission occurs when a cell divides evenly to form two new cells (Figure 2.20).

• *Budding:* Budding occurs when a cell divides unevenly.

• *Multiple fission (schizogony):* Multiple fission is when the nucleus of the cell divides multiple times before the rest of the cell divides. Forms around each nucleus when the nucleus divides then each nuclei separates into a daughter cell.

Activity 2.6

Be in a group of 5 students, select one group leader and read your textbook and tell your understanding to the leader and finally discuss together the characteristics and economic importance of some common protozoa. If you have, any difficulties invite your teacher to clarify for you.

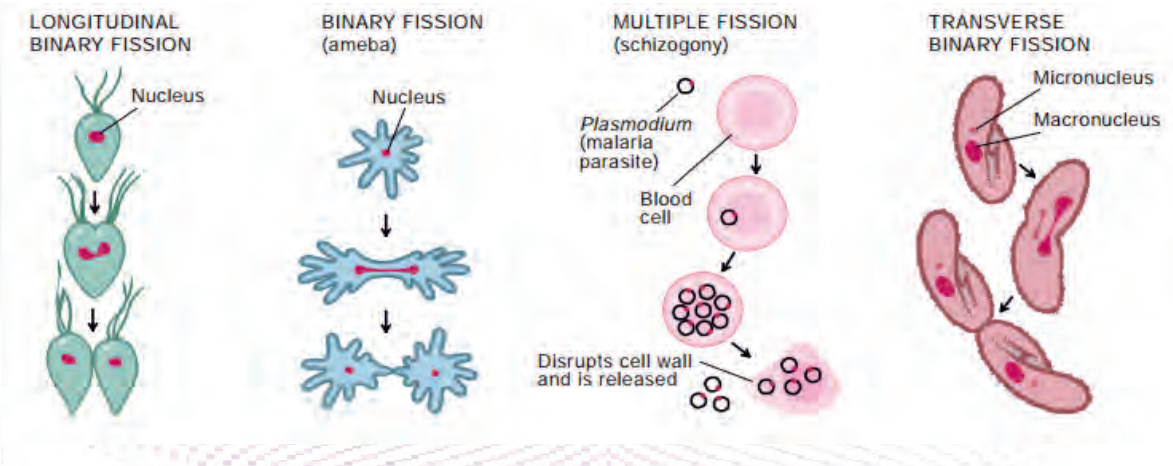


Figure 2.20 Asexual reproduction in protozoa

Sexual reproduction also occurs during the life cycle of most protozoa. A distinctive feature of ciliates is the presence of two types of nuclei: tiny micronuclei and large macronuclei. A cell has one or more nuclei of each type. Genetic variation results from **conjugation (Figure 2.21)**, a sexual process in which two individuals exchange haploid micronuclei but do not reproduce. Ciliates generally reproduce asexually by binary fission, during which the existing macronucleus disintegrates and a new one is formed from the cell's micronuclei. Each macronucleus typically contains multiple copies of the ciliate's genome. Genes in the macronucleus control the everyday functions of the cell, such as feeding, waste removal, and maintaining water balance.

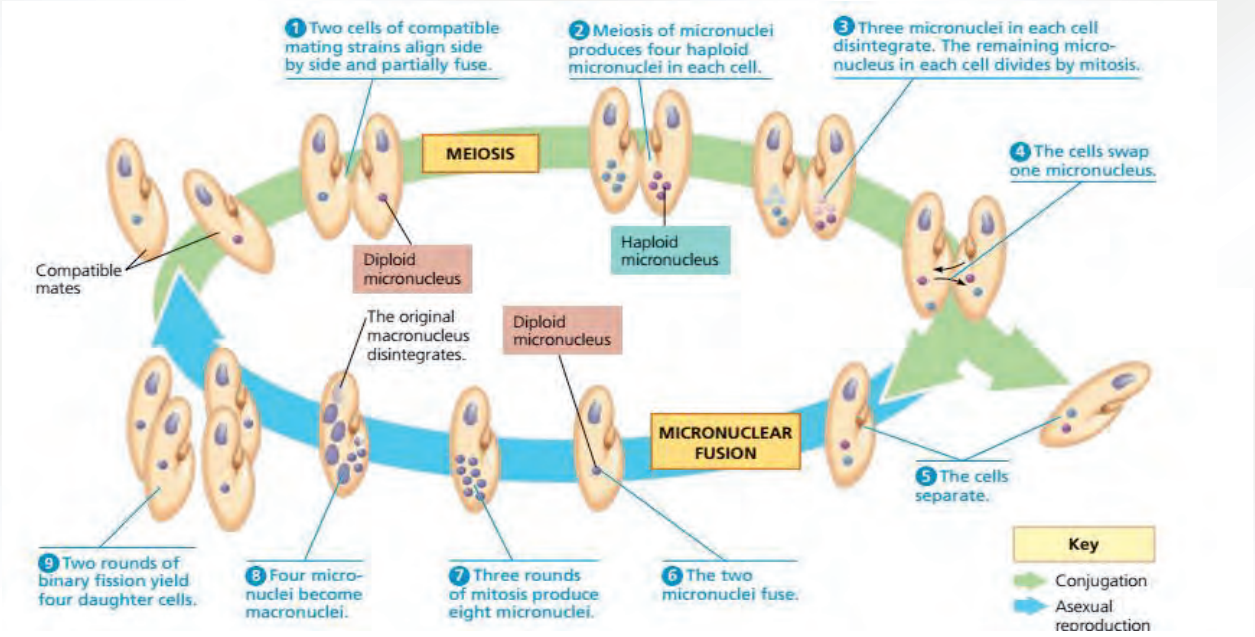


Figure 2.21. Conjugation in Paramecium

Nutrition in Protozoans

Protists receive nutrients by breaking down organic matter (*heterotrophic*) and can grow in both aerobic and anaerobic environments, such as protists that live in the intestine of animals. Some protists, such as *Euglena*, receive nutrients from organic matter and through photosynthesis because they contain chlorophyll. These protists are considered both algae and protozoa. Protists obtain food in one of three ways:

- **Absorption:** Food is absorbed across the protist's plasma membrane.
- **Ingestion:** Cilia outside the protist create a wave-like motion to move food into a mouth-like opening in the protist called a *cytosome*. An example is the paramecium.
- **Engulf:** Pseudopods (meaning "false feet") on the protist engulf food, then pull it into the cell using a process called *phagocytosis*. An example of this type of protist is the amoeba.

Self-questioning

- Can protozoan reproduce?
- How do Amoeba, Euglena, and Paramecium reproduce?
- Draw and label the structure of Amoeba, Euglena, and Paramecium.

Food is digested in the vacuole after the food enters the cell. The *vacuole* is a membrane-bound organelle. Waste products are excreted using a process called exocytosis.

2.4.1.Common diseases caused by protozoa

Most **protozoas** are not harmful but there are a few disease-causing protozoans. Many types of protozoa are even beneficial in the environment because they help make it more productive. They improve the quality of water by eating bacteria and other particles. Some of the human diseases caused by protozoans include malaria, African trypanosomiasis, amoebiasis, giardiasis, chagas disease, leishmaniosis, toxoplasmosis, and cryptosporidiosis (Figure 2.22).

Table 2.6. Major protozoal parasites of human and other organisms

Disease	Causative agent	**Organs affected**	**Transmission /vector**	**Clinical Features**
Amoebiasis	Entamoeba histolytica	Intestine, liver	Ingestion of fecally contaminated food or water; disease associated with poverty, homosexual men, and migrant workers	Multiplication of the organisms and tissue destruction in the intestine and in other body tissues can result in amebic abscesses. The irritating effect of the amebas on the cells lining the intestine causes intestinal cramps and diarrhea. Due to intestinal ulceration, the diarrheal fluid is often bloody, and the condition is referred to as amebic dysentery
Giardiasis	Giardia lamblia	Intestine	Ingestion of fecally contaminated water; person-to-person, in day care centers	Ingested cysts survive stomach passage; trophozoites emerge from the cysts in the small intestine, where some attach to epithelium and others move freely; mucosal function is impaired by adherent protozoa and host immune response.
Trichomon	Trichomonas vaginalis	Urogenital	Sexual contact	Vaginal discharge, odor and edema or erythema

Disease	Causative agent	**Organs affected**	**Transmission /vector**	**Clinical Features**
iasis		organs		
African sickness	Trypanosoma brucei	Blood, brain	Tsetse fly (*Glossina*)	Initial haemolytic phase (fever, joint pains followed by neurological disorder, somnolence)
Leishmaniasis (kala-azar)	Leishmania donovani	White blood cells, skin, intestine	Sand fly (Phlemotomus)	Skin ulcers, mucocutaneous complications and visceral diseases (hepatosplenomegaly)
Malaria	Plasmodium spp.	Liver, red blood cells	Mosquito (Anopheles)	Fever, shivering, cough, respiratory distress, pain in the joints, headache, watery diarrhea, vomiting, convulsions, severe anemia
Toxoplasmosis	Toxoplasma gondii	Blood, eye	Domestic cats, food	Blindness and mental retardation can result in congenitally infected children. Immunosuppressed patients can present more severe symptoms: splenomegaly, polymyositis, dermatomyositis, chorioretinitis, myocarditis, pneumonitis, hepatitis, encephalitis, and multisystem organ failure.

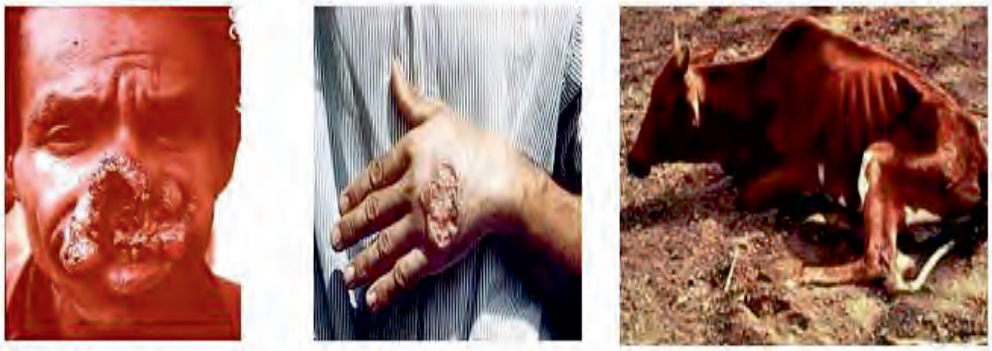


Figure 2.22. Leishmaniasis and trypanosomiasis

By the end of this section, the student will be able to:

- give a brief definition of viruses.
- describe the structures of a virus
- explain the characteristics of viruses.
- label the structures of viruses.
- justify why viruses must find an appropriate host cell to replicate themselves.
- classify viruses as RNA viruses and DNA viruses.
- explain the mechanism of replication viruses.
- Distinguish between lytic and lysogenic cycle of a virus.
- Mention the common viral diseases in Ethiopia.
- Describe the ways of transmission and prevention of HIV/AIDS, Hepatitis B.

Self-questioning

- What are Babesia and Theileria?
- State the common species of plasmodium in Ethiopia.
- Explain the causative agent and vector of Nagana(Gendi).
- Describe the vector and life cycle of leshimania spp.
- State the routes of transmission of Giardia and amoeba.
- Show the life cycle of plasmodium spp. and describe their ecology.

2.5. Viruses

Self-questioning

- Why we studying viruses? Discuss in-group and present to your class.
- How viruses differ from other organisms?
- Write in brief the general features and occurrence of viruses.

Keyword

A virus is a very small, non-cellular parasite of cells. Its genome, which is composed of either DNA or RNA, is enclosed in a protein coat. Viruses are different from other micro-organisms because they have no cellular organelles and so cannot carry out any metabolic processes; they must all enter other cells to reproduce

Viruses are small, obligate, intracellular particles; that is, most can be seen only with the electron microscope (Figure 2.23) and they must infect and take over a host cell in order to replicate. This is because they lack the chemical machinery for generating energy and synthesizing large molecules. Viruses, therefore, must find an appropriate host cell in which they can replicate—and, as a result, often cause disease.

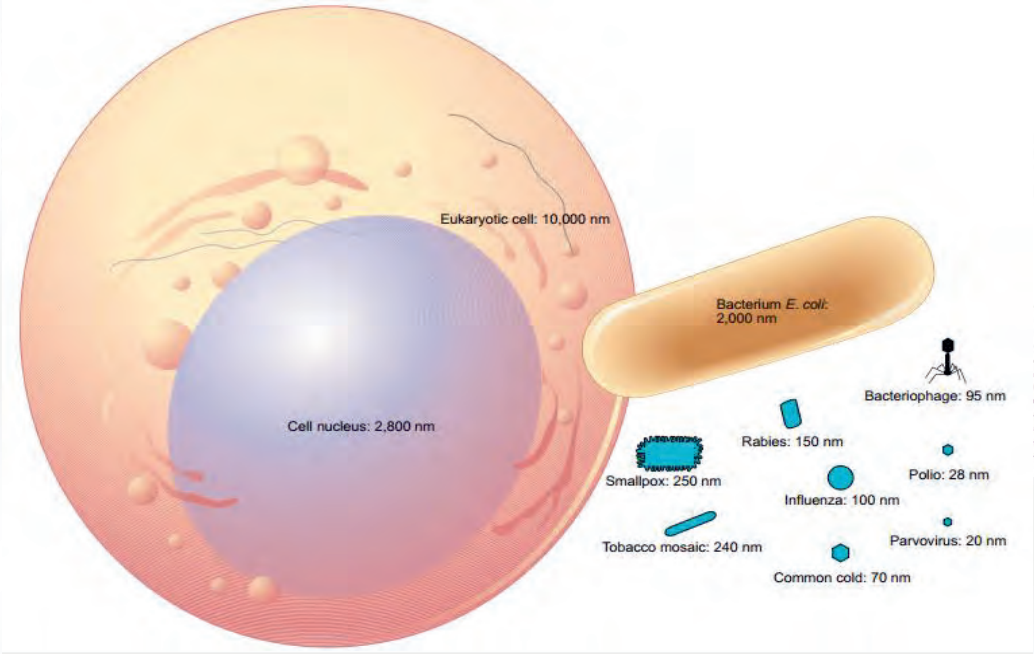


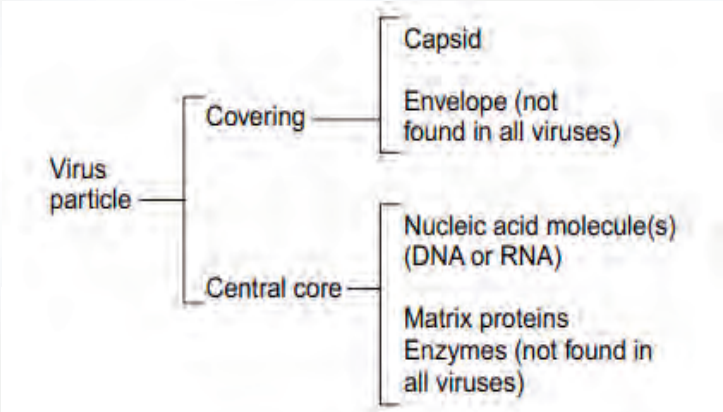
Figure 2.23. Variations in size among eukaryotic cells, prokaryotic cells and viruses

2.5.1.Characteristics of virus

- Viruses have an inner core of nucleic acid surrounded by protein coat known as an envelope.
- They cannot be grown on artifcial cell free media (However, grow in animals, eggs or tissue culture).
- Viruses do not have a cellular organization. They do not have cell wall or cell membrane or cellular organelles including ribosomes.
- They do not occur free in nature but act as obligate intracellular parasite.
- They lack the enzymes necessary for protein and nucleic acid synthesis and are dependent for replication on the synthetic machinery of host cells.
- They are unaffected by antibacterial antibiotics.
- Viruses are inert (nucleoprotein) filterable Agents
- Virus occupy a space in between living and non-living, because they are crystallizable and non-living outside the body of host.
- Obligate intracellular parasites of bacteria, protozoa, fungi, algae, plants, and animals.
- Ultramicroscopic size, ranging from 20 nm up to 450 nm (diameter)
- Do not independently fulfill the characteristics of life
- Inactive macromolecules outside the host cell and active only inside host cells
- Basic structure consists of protein shell (capsid) surrounding nucleic acid core.
- Nucleic acid of the viral genome is either DNA or RNA but not both.
- Nucleic acid can be double-stranded DNA, single-stranded DNA, single-stranded RNA, or double-stranded RNA.
- Molecules on virus surface impart high specif city for attachment to host cell.
- Multiply by taking control of host cell's genetic material and regulating the synthesis and assembly of new viruses
- Lack machinery for synthesizing proteins

Structure of viruses

A basic structure of virus is nucleic acid core (either DNA or RNA but not both) surrounded by protein coat (Figure 2.24). Central core of nucleic acid of a virus is called genome and the protein coat surrounding is called as capsid. In some virus, an envelope made up of glycoprotein and phospholipid bilayer is present outside the capsid.



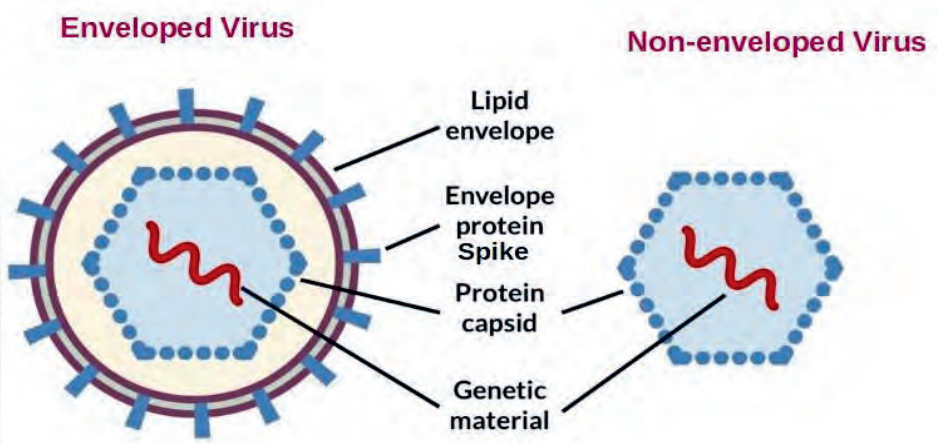


Figure 2.24. Viral Structure:

The basic structural components of a virus are:

Viruses have a very simple structure consists of the following

- Core-the genomic material, either DNA or RNA. DNA or RNA may be single-stranded or double stranded
- Capsid-a protective coat of protein surrounding the core
- Nucleocapsid-the combined structure formed by the core and capsid
- Envelope- a few viruses, such as the HIV and influenza viruses, have an additional lipoprotein layer around the capsid derived from the cell surface membrane of the host cell.
- Capsomeres- capsids are often built up of identical repeating subunits called capsomeres.
- Some virus contains enzymes which play central role during infection process. E.g., Some bacteriophage contains an enzyme

lysozyme, which makes small hole in bacterial cell that allows viral nucleic acid to get in. Some virus contains their own nucleic acid **polymerase** which transcribe the viral genome into mRNA during replication process. E.g., Retrovirus are RNA virus that replicates inside host cell as DNA intermediate. These viruses possess an **RNA dependent DNA polymerase** called **reverse transcriptase**.

2.5.2.Viral symmetry

1. Helical symmetry

There are several viruses found with a **helical** morphology. These viruses consist of identical protein subunits or protomers which assembled in a **helical** structure around the genome (Figure 2.14). This type of protein subunits generally forms a rigid nucleocapsid. Moreover, the helical structure provides flexibility to the filaments. The most common example of a helical virus is the tobacco mosaic virus. Apart from that Sendai virus is also reported to have a helical structure.

1. Icosahedral Symmetry

An icosahedron structure refers to a type of **polyhedron** with 20 equilateral triangular faces and 12 vertices. The rigid structure provides protection to the genome (Figure 2.14). The common examples of viruses reported to have an icosahedral structure are papovavirus, picornavirus, adenovirus, toga virus, etc.

2. Complex Symmetry

These groups of viruses do not come under the above-motioned groups. These viruses consist of complex structural components which made it different from the other two groups (Figure 2.25). A common example of this group of the virus is the pox virus.

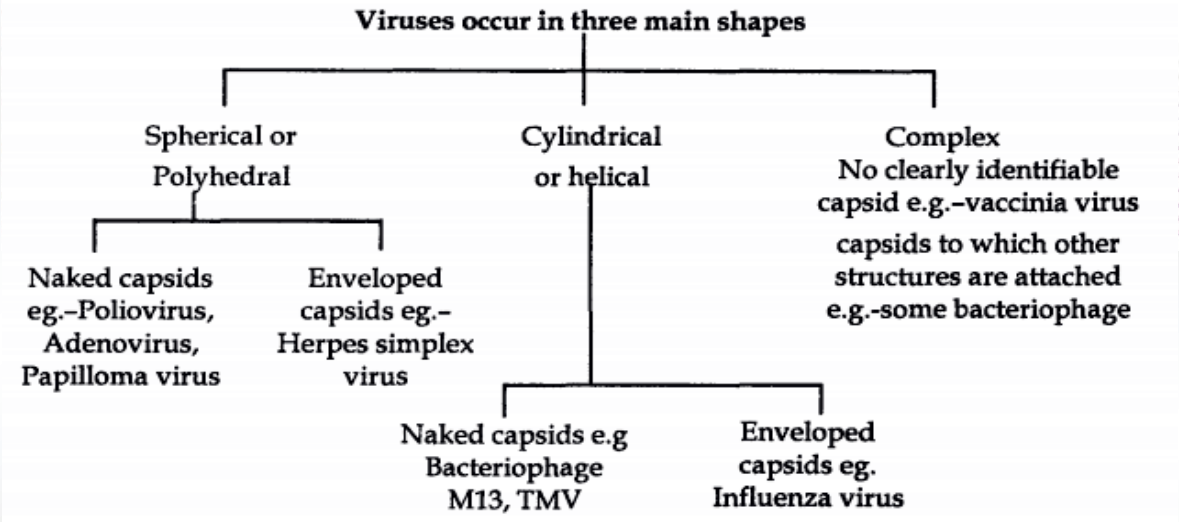


Figure 2.25. Viral classification based ontheir structures

Difference between DNA & RNA Viruses

- The viruses that contain DNA as their genetic material are called the DNA viruses. RNA viruses, on the other hand, contain RNA as their genetic material.
- DNA viruses are mostly double-stranded while RNA viruses are single-stranded.
- RNA mutation rate is higher than the DNA mutation rate.
- DNA viruses replicate in the nucleus while RNA viruses takes place in the cytoplasm.

Activity 2.7

- Be in groups of 5-10, discuss, and give an illustrated explanation on the morphology and chemical structure of viruses and write an essay on multiplication of animal viruses.
- What do you know about bacteriophages? What is it use in biotechnology?

Viruses infect all cellular life forms: eukaryotes (vertebrate animals, invertebrate animals, plants, fungi) and prokaryotes (bacteria and archaea). The viruses that infect prokaryotes are often referred to as bacteriophages, or phages for short.

Self-questioning

- What are the bases for classification of viruses?
- List the different shapes of the virus.
- Do you think viruses are essential for human being? If yes, in what way?
- Can viruses reproduce? What does it mean by the lytic and lysogenic cycle?

? Did you know?

The particle of a virus is called a virion. All virions contain at least two components:

? A protein shell or capsid

? DNA or RNA as the genetic material

? Some also have:

? A membrane made from lipids and proteins outside the capsid

? Other proteins and enzymes inside the capsid

HIV (human immunodeficiency virus) is a virus that attacks the body's immune system. If HIV is not treated, it can lead to AIDS (acquired immunodeficiency syndrome). Learning the basics about HIV can keep you healthy and prevent HIV transmission

KEY WORDS

DNA virus contains genetic information stored in the formof DNA

RNA virus contains genetic information stored in the formof RNA

Retrovirus an RNA virus that converts its genetic information from RNA intoDNA after it has infected ahost

Bacteriophage a virus that uses a bacterium to replicate its genetic information

2.5.3.Classification of Viruses

Today, the primary criteria for delineating the main viral taxa are:

(1) the type and character of the viral genome,

(2) the strategy of viral replication, and

(3) the types of organisms they infect.

Self-questioning

- What are Retroviruses?
- How does HIV reproduce and cause AIDS?
- Can AIDS be treated?
- What is the social and economic impact of AIDS?
- Draw the structure of HIV.
- What is HIV surface spikes made from? What is the importance of HIV spikes?
- What is the reproductive cycle of bacteriophages is?

Viral Replication

A virus invades a living host cell a thousand or more times its size, hijacks the metabolism of the cell to produce copies of itself, and often destroys the host cell when new virions (a completely assembled virus outside its host cell) are released.

Replication has been studied in a wide range of viruses and their host cells. We examine the bacteriophages first and then discuss the animal viruses. One of the best studied processes of replication is that carried out by bacteriophages of the T-even group (T for "type").

In general, viruses go through the following five steps in their **replication cycles** to produce more virions:

1. Adsorption, the attachment of viruses to host cells.

2. Penetration, the entry of virions (or their genome) into host cells.

3. Synthesis, the synthesis of new nucleic acid molecules, capsid proteins, and other viral components within host cells while using the metabolic machinery of those cells.

4. Maturation, the assembly of newly synthesized viral components into complete virions.

5. Release, the departure of new virions from host cells. Release generally, but not always, kills (lyses) host cells.

Bacteriophage

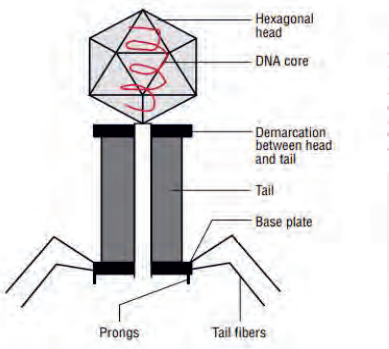


Figure 2.26. bacterioph

Component	Function
Genome	Carries the genetic information necessary for replication of new phage particles
Tail sheath	Retracts so that the genome can move from the head into the host cell's cytoplasm
Plate and tail fibers	Attach phage to specific receptor sites on the cell wall of a susceptible host bacterium

Bacteriophages are bacterial viruses. They are the viruses that infect bacteria. They are obligate intracellular parasites that multiply inside bacteria by making use of some or all of the host biosynthesis machinery. They are also called ***phages***.

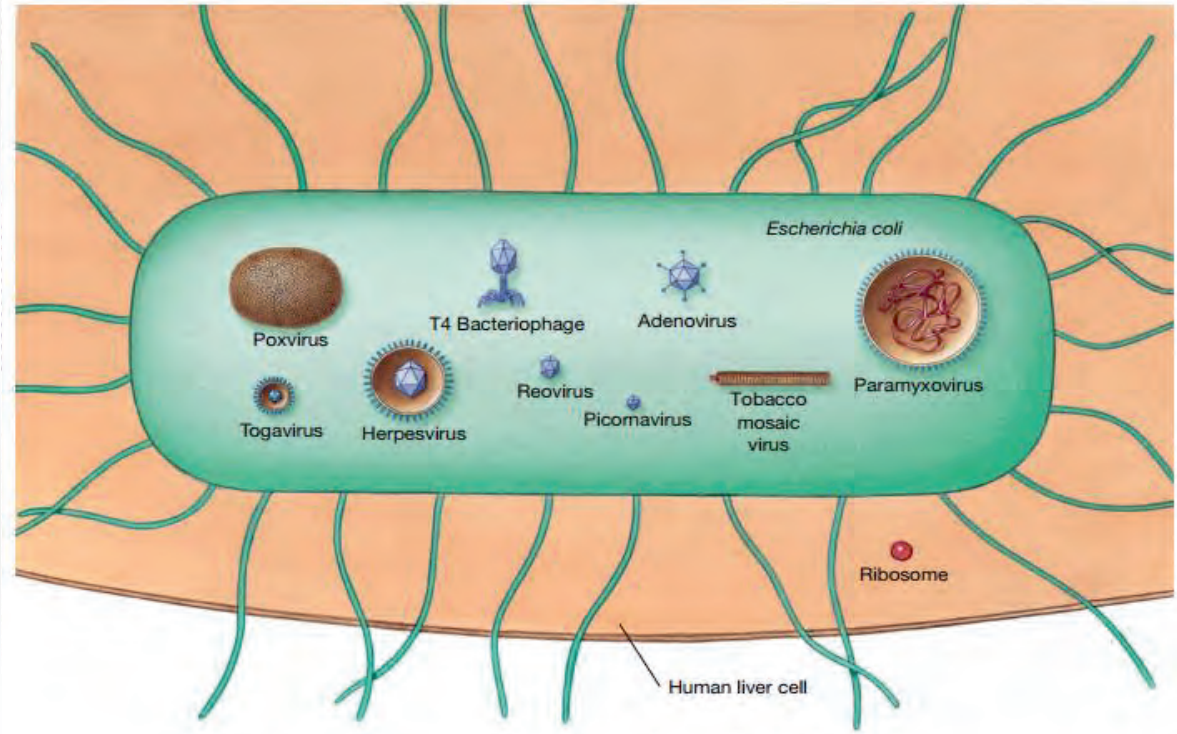


Figure 2.27. Variations in shapes and sizes of viruses compared with a bacterial cell, an animal cell, and a eukaryotic ribosome .

Phages exhibit two different types of life cycle:

Lytic cycle: also known as virulent cycle. In this cycle, intracellular multiplication of the phage results in the lysis of host bacteria, resulting in release of progeny virions (Figure 2.28).

The enzyme lysozyme, which is coded for by a phage gene, breaks down the cell wall, allowing viruses to escape. In the process the bacterial host cell is lysed. Thus, phages such as T4 are called virulent (lytic) phages because they lyse and destroy the bacteria they infect. The released phages can now infect more susceptible bacteria, starting the infection process all over again. Such infections by virulent phages represent a lytic cycle of infection.

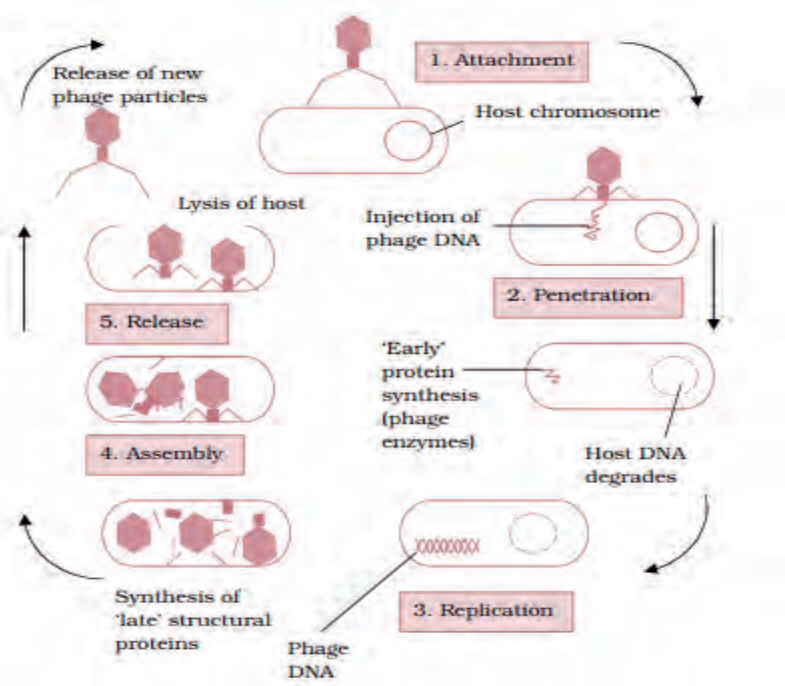


Figure 2.28. The lytic cycle of phage T4

Lytic cycle of bacteriophage (Replication of a virulent bacteriophage). A virulent phage undergoes a lytic cycle to produce new phage particles within a bacterial cell. Cell lysis releases new phage particles that can infect more bacteria).

Lysogenic cycle: Infection with every phage does not result in lysis of the host cells (Figure 2.29). Unlike virulent phages, which cause lysis of the host cell, some phages (such as temperate phages) integrate into the genome of the bacterial chromosome without causing any lysis of the bacteria.

The integrated phage nucleic acid is known as the prophage. The prophage behaves like a segment of the host chromosome and multiplies synchronously with it. This phenomenon is

known as lysogeny. The bacterium that carries a prophage within its genome is called lysogenic bacterium and such phages are called lysogenic or temperate phages.

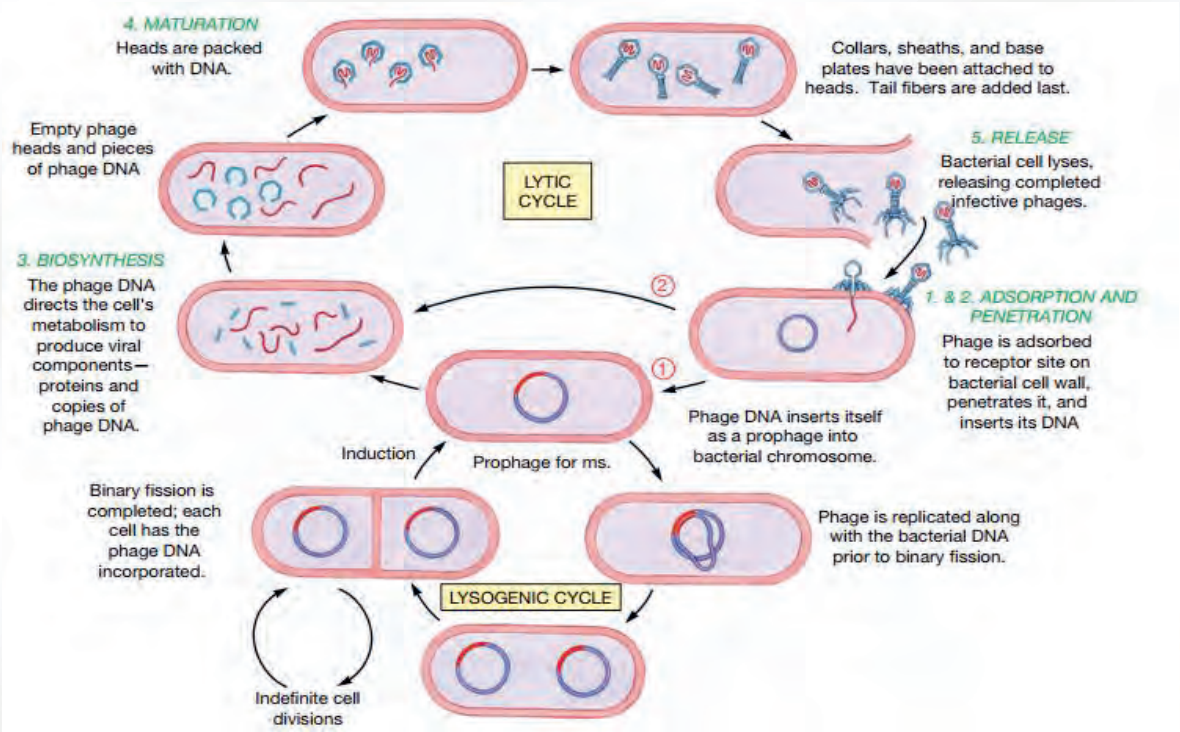


Figure 2.29. Lysogenic bacteriophage cycle (Replication of a temperate bacteriophage).

- What are the differences between lytic and lysogenic cycle

TG. Lytic vs Lysogenic Cycle

Lytic Cycle	**Lysogenic Cycle**
The DNA of the virus doesn't integrate into the host DNA	The DNA of the virus integrates into the host DNA
Host DNA hydrolyzed	Host DNA not hydrolyzed
Absence of prophage stage	Presence of prophage stage
DNA replication of virus takes place independently from the host DNA replication	DNA replication of the virus takes place along with the host DNA replication
Occurs within a short period of time	Takes time

Lytic Cycle	Lysogenic Cycle
Symptoms of viral replication are evident	Symptoms of viral replication not evident
Genetic recombination in the host bacterium not allowed	Genetic recombination in the host bacterium allowed
The cellular mechanism of the host cell is totally undertaken by the viral genome	The cellular mechanism of the host cell is somewhat disturbed by the viral genome

Common viral diseases in Ethiopia

A **viral disease** is any condition that's caused by a **virus**. There are several types of **viral disease**, depending on the underlying **virus**.

Table 2.7. Viral diseases

Disease	Causative agent	Sign and symptoms	Transmission	Prevention and control
Mumps	Mumps virus	Swollen and paifull protid glands .pain on chewing and swallowing	Person to person in infected saliva	vaccine
Measles (rubeola)	Measles virus	Caugh, nasal discharge, eye redness, and high fever,	Droplet contact	vaccine
Rabies	Rabies virus	Tingling, burning, coldness at bite site , Fever, headache, increased muscle, tension, Paralysis and hydrophobia	Bite from rabid animals	Avoiding rabid animals, thoroughly washing bitten area, pre-

Disease	Causative agent	Sign and symptoms	Transmission	Prevention and control
				exposure vaccination when needed
Polio	Polio virus	Often no sign and symptoms	Fecal-oral-route	Polio vaccine, good personal hygien
Common cold ((rhinitis)	Rhinoviruses Adeno viruses & other viruses	Sneezing, sore throat, runny and stuffy nose, hacking cough	Respiratory droplets	Practicing good hygien
Chickenpox ((varicella)	Varicella-zoster virus	Fever, headache, malaise with red, itchy rash on face, scalp, chest, and back	Droplet contact	Hickenpox vaccine

2.6. Normal microbionta

At the end of this lesson, student will be able to:

- Define the normal microbionta.
- Distinguish between resident and transient microbiota.
- Mention three protective roles of the normal microbiota.
- Explain how the composition of the normal microbiota can change over time.
- Describe germ theory of diseases.
- State atleast three postulates formulated by Koch.
- Justify how the Koch's experimental procedure contributed to the advancement microbiological techniques

? What is the role of bacteria and other microorganisms in infectious diseases?

? How do we benefit from the reduction of vitamin K by microbes?

The **normal microbiota** is the population of microorganisms routinely found growing on the body of healthy individuals. Microbes that typically inhabit body sites for extended periods are resident microbiota, whereas temporary occupants are transient microbiota (Figure 2.30).

There are many reasons to acquire knowledge of the normal human microbiota. Three specific examples include:

1. An understanding of the different microorganisms at particular locations provides greater insight into the possible infections that might result from injury to these body sites.

2. A knowledge of the normal microbiota helps the physicianinvestigator understand the causes and consequences of colonization and growth by microorganisms normally absent at a specific body site.

3. An increased awareness of the role that these normal microbiota play in stimulating the host immune response can be gained. This awareness is important because the

immune system provides protection against potential pathogens.

Considering how important this population is to human health, relatively little is known about its members. The normal human microbiontal have protective role from diseases causing microorganisms. One of the most significant contributions of the normal microbiota to health is protection against pathogens. The normal microbiota excludes pathogens by;

(1) covering binding sites that might otherwise be used for attachment,

(2) consuming available nutrients,

(3) producing compounds toxic to other bacteria,

4) to stimulate the adaptive immune system.

When members of the normal microbiota are killed or their growth suppressed, as can happen during antibiotic treatment, pathogens may colonize and cause disease. For example, Oral antibiotics can also inhibit members of the normal intestinal microbiota, allowing the overgrowth of toxin-producing strains of *Clostridium difficile* that cause antibiotic-associated diarrhea and colitis.

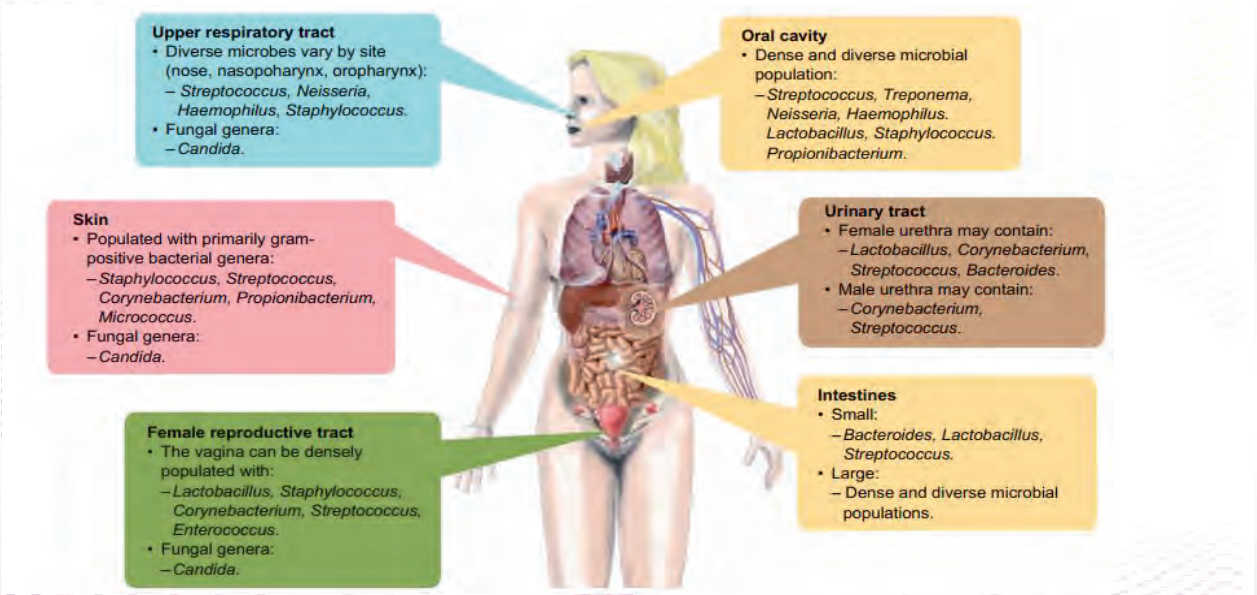


Fig 2. 30. Normal microbionta of the human body

The Germ Theory of Disease and Koch's Postulates

In order to prove whether or not diseases are caused by microorganisms, Koch used mice as experimental animals. Using appropriate controls, Koch demonstrated that when a small amount of blood from a diseased mouse was injected into a healthy mouse, the latter quickly developed anthrax. He took blood from this second animal, injected it

into another, and again observed the characteristic disease symptoms (Figure 2.31). However, Koch carried this experiment a critically important step further. He discovered that the anthrax bacteria could be grown in nutrient fluids outside the host and that even after many transfers in laboratory culture, the bacteria still caused the disease when inoculated into a healthy animal. On the basis of these experiments and others on the causative agent of tuberculosis, Koch formulated a set of rigorous criteria, now known as Koch's postulates, for definitively linking a specific microorganism to a specific disease. Koch's postulates state the following:

1. The disease-causing organism must always be present in animals suffering from the disease but not in healthy animals.

2. The organism must be cultivated in a pure culture away from the animal body.

3. The isolated organism must cause the disease when inoculated into healthy susceptible animals.

4. The organism must be isolated from the newly infected animals and cultured again in the laboratory, after which it should be seen to be the same as the original organism

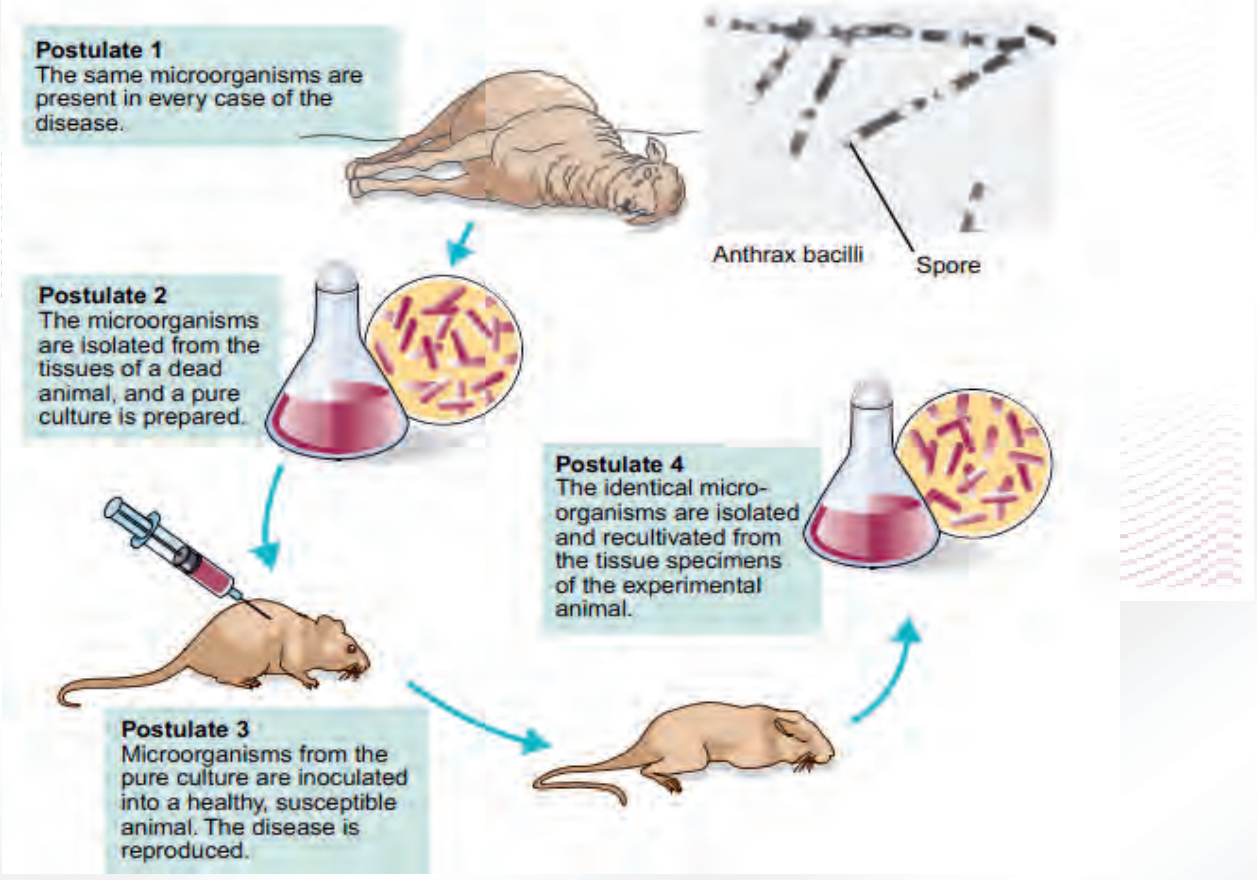


Figure 2.31. Koch's postulate

Self-qestioning

? What is an infectious disease is?

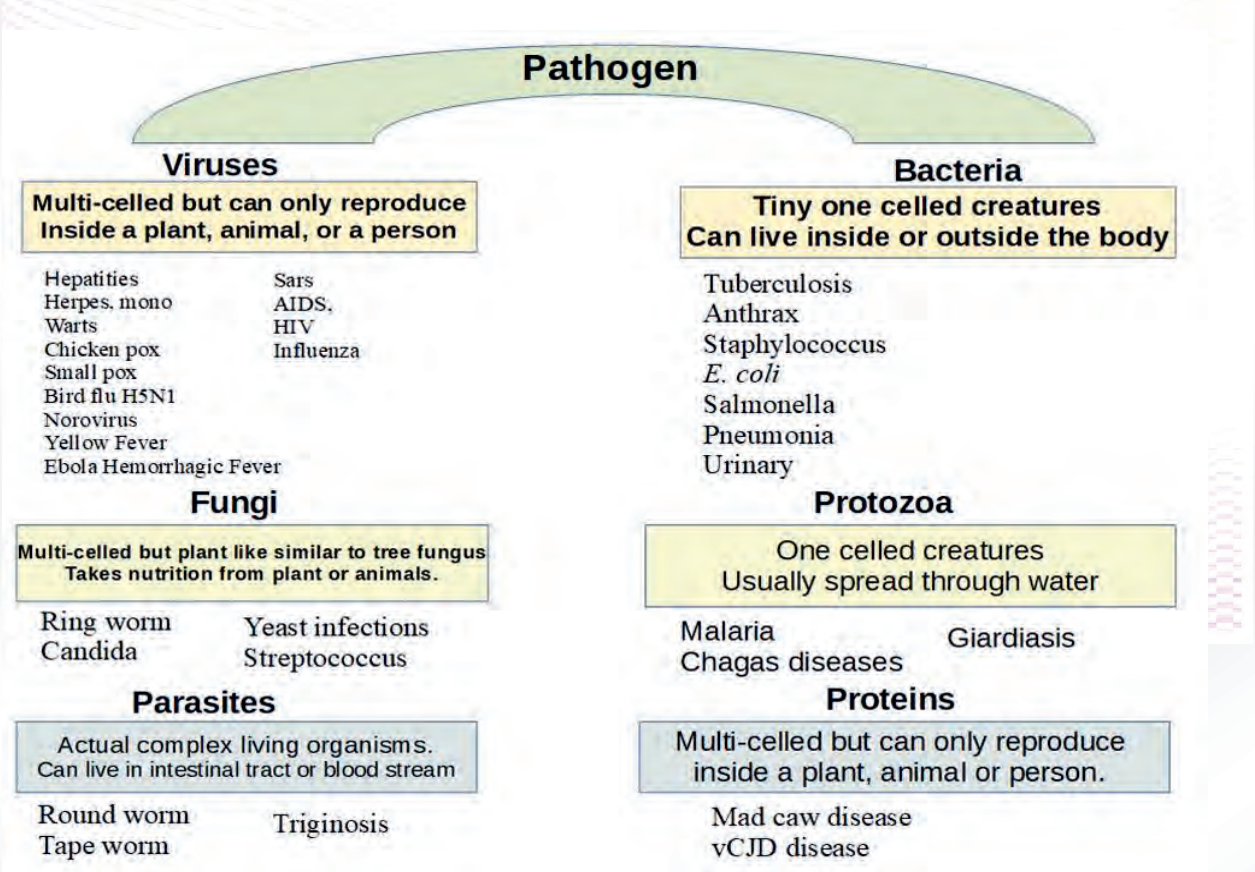
? How will you prove that microorganisms can cause disease?

? How are normal microbiota beneficial?

? Which are the common disease causing microorganisms?

Keywords

- **Normal microbiota or flora**: are the microorganisms that live on another living organism (human or animal) or inanimate object without causing disease.
- **Immune system**: is a complex network of cells, tissues, organs, and the substances they make that helps the body fight infections and other diseases.
- **Inflammatory response**: is a complex biological reaction of the body, which appears when healthy tissues are wounded by physical/chemical stimuli or are invaded by bacteria, viruses, or toxins.



Activity 2.8

Make six groups in a classroom and take one group of organisms among bacteria, fungi, protozoa (malaria, amoeba, and giardia), and virus for each group to study their life cycles and biology using the Jigsaw method. Use your textbook and picture prompt for each group of organisms. Students can also use drama method or role-play (Hint-some students can act as doctor and others as patients) to learn about the cause, symptom, prevention, and treatment method.

2.7. Modes of disease transmission and ways of prevention

Microorganisms are transmitted in health care settings by four main routes:

- Contact
- Droplet
- Airborne
- Common vehicle

At the end of this lesson, student will be able to:

- describe the modes of disease transmission.
- give examples of airborne diseases.
- give examples of food and waterborne diseases.

Table 2.8. Modes of disease transmission

Method of transmission	**How the transmission route works**	**Examples of diseases**
Droplet infection	Many of these diseases are 'respiratory diseases' – diseases affecting the airways of the lungs. The organisms are carried in tiny droplets through the air when an infected person coughs or sneezes. They are inhaled by other people.	Common cold, 'flu, pneumonia
Drinking contaminated water	The micro-organisms transmitted in this way often infect regions of the gut. When unclean water containing the organisms is drunk, they colonise a suitable area of the gut and reproduce. They are passed out with faeces and find their way back into the water.	Cholera, typhoid fever
Eating contaminated food	Most food poisoning is bacterial, but some viruses are transmitted this way. The organisms initially infect a region of the gut.	Salmonellosis, typhoid fever, listeriosis, botulism
Direct Contact	Many skin infections, such as athlete's foot, are spread by direct contact with an infected person or contact with a surface carryingthe organism.	Athlete's foot, ringworm
Sexual intercourse	organisms infecting the sex organs can be passed from one sexual partner to another during intercourse. Some	Candidiasis, syphilis, AIDS,

Method of transmission	How the transmission route works	Examples of diseases
	are transmitted by direct body contact, such as the fungus that causes candidiasis (thrush). others are transmitted in semen or vaginal secretions, such as the AIDS virus. Some can be transmitted in saliva, such as syphilis.	gonorrhoea
Blood-to-blood contact	Many of the sexually transmitted diseases can also be transmitted by blood-to-blood contact. Drug users sharing an infected needle can transmit AIDS.	AIDS, hepatitis B
Animalvectors	Many diseases are spread through the bites of insects. Mosquitoes spread malaria and tsetse flies spread sleeping sickness. in both cases, the disease-causing organism is transmitted when the insect bites humans in order to suck blood. Flies can carry micro- organisms from faeces onto food.	Malaria, sleeping sickness

Activity 2.9: Identifying sources of infection

For each of the methods of transmission given in table 2.4, identify the reservoir of infection

2.8. Uses of microorganisms

At the end of this lesson, student will be able to:

- explain the various uses or application of microorganisms.
- Explain the medical application .
- Describe how vector borne diseases are transmitted.

Self-questioning

? What happens to the body of an animal when it dies? Why?

? What do you think the economic or beneficial uses of microorganisms?

Through the years, microbiologists have made great steps in discovering how microorganisms work, and application of this knowledge has greatly advanced human health and welfare.

Besides understanding microorganisms as agents of disease, microbiology has made great advances in understanding the important role that microorganisms play in food and agriculture, and microbiologists have been able to exploit microbial activities to produce valuable human products, generate energy, and clean up the environment.

Agriculture

Microorganisms play an important role in agriculture. The microorganisms include bacteria, fungi, algae, protozoa, viruses. Microorganisms help in organic matter decomposition, humus formation.

The important role of microorganisms includes nitrogen fixation, phosphate solubilization, potassium mobilization, antagonism towards pathogens, pests. Hence, the role of microorganisms in agriculture is indispensable (Figure 2.32).

The chemical elements carbon, nitrogen, oxygen, sulfur, and phosphorus are essential for life and abundant, but **not necessarily in forms that organisms can use.** Therefore, microorganisms are primarily responsible for converting these elements into forms that plants and animals can use. Microorganisms, especially bacteria and fungi, return carbon

dioxide to the atmosphere when they decompose organic wastes and dead plants and animals. Algae, cyanobacteria, and higher plants use the carbon dioxide during photosynthesis to produce carbohydrates for animals, fungi, and bacteria. Nitrogen is abundant in the atmosphere but in a form not usable by plants and animals. Only bacteria can naturally convert atmospheric nitrogen to a form available to plants and animals (nitrate) (Figure 2.19).

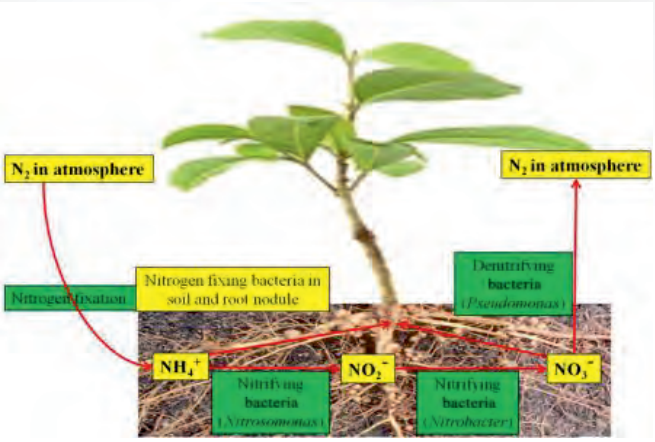


Figure 2.32. The role of micororganisms in agriculture

Sewage treatment

Anaerobic bacteria are used in wastewater treatment on a normal basis. The main role of these bacteria in sewage treatment is to reduce the volume of sludge and produce **methane gas** from it. **Methane gas** can be used as an **alternative energy source**. This is a huge benefit considering the already high wastewater treatment energy consumption levels. **Phosphorus removal** from wastewater is another benefit of anaerobic microbes used in sewage treatment (Figure 2.33).

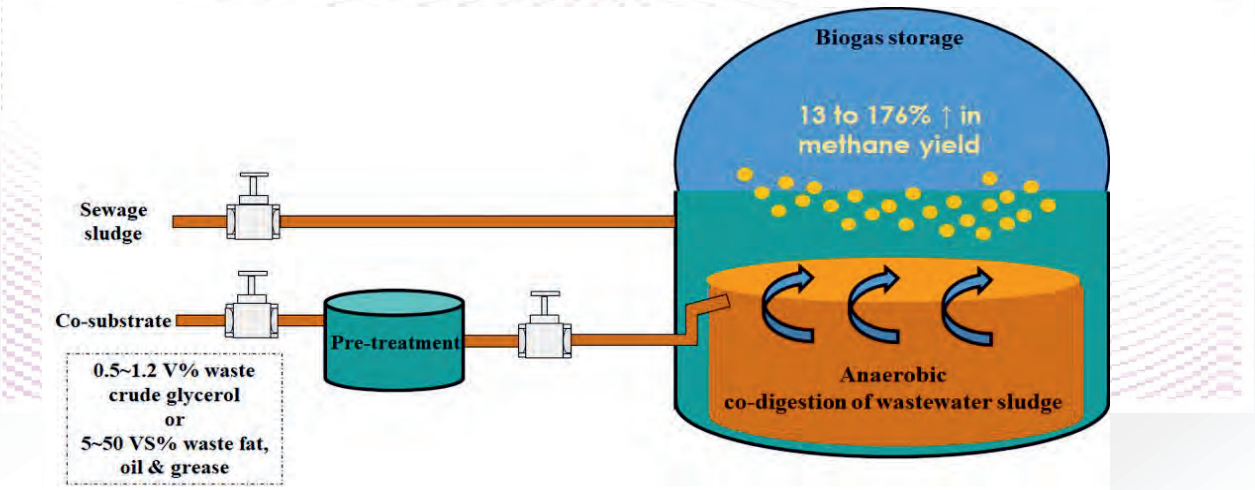


Figure 2.33. Anaerobic co digestion of waste water

Bioremediation

Bioremediation is a natural process that relies on microorganisms and plants and/or their derivatives (enzymes or spent biomass) to degrade or alter environmental contaminants as these organisms carry out their normal life functions. As defined, microbial bioremediation makes use of microorganisms and/or their derivatives (enzymes or spent biomass) to clean-up environmental contaminants.

It is important to note that microorganisms are everywhere and as such pollutants in the different environmental compartments always come into contact with microorganisms. Microbes break down/transform pollutants via their inherent metabolic processes with or without slight pathway modifications to allow the pollutant to be channeled into the normal microbial metabolic pathway for degradation/and biotransformation.

Applied bioremediation methods therefore focus on tapping the naturally occurring microbial catabolic capabilities to degrade, transform or accumulate most of the synthetic compounds such as hydrocarbons (e.g., oil), polychlorinated biphenyls (PCBs), polyaromatic hydrocarbons (PAHs), radionuclides and metals. The natural existence of a large diversity of microbial species expands the variety of chemical pollutants that are degraded or detoxified.

Bioremediation is a natural process, it takes a little time, as an acceptable waste treatment process for contaminated material such as soil. Microbes able to degrade the contaminant and increase in numbers when the contaminant is present. When the contaminant is degraded, the biodegradative population declines. The residues for the treatment are usually harmless products including water, carbon dioxide and cell biomass.

Food production and processing

The tart taste of yogurt, pickles, sharp cheeses, and some sausages is due to the production of lactic acid by one or more members of a group of bacteria known as the lactic acid bacteria. These bacteria - including species (Figure 2.34) of *Lactobacillus, Lactococcus, Streptococcus, Leuconostoc,* and *Pediococcus* are obligate fermenters that characteristically produce lactic acid as an end product of their metabolism. Some also produce flavorful and aromatic compounds that contribute to the overall quality of fermented foods.

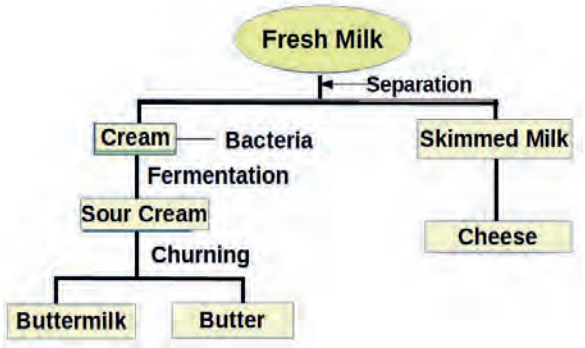


Figure 2. 34. The role of Bacteria in Butter production

Medicine

It is very difficult to decode the human genome if any disorders occur in it as humans are the eukaryotic organisms. It means their body consists of various types pf cells and they are all differentiated into different tissues and organs. Microorganisms have made it possible to make such medicines which when enter the body, target the defected genes and make healthy changes in them and they become functional again. There is a common example of human insulin (Figure 2.35). Insulin is an medicine which is prescribed for the diabetic patients. Now it is possible to synthesize the insulin in microorganisms like bacteria and yeast.

These microorganisms are inserted in the body in the form of vectors and cure the defected genes. Due to the availability of microorganisms in the environment, scientists have made use of them for making many medicines and drugs and also used them for drug delivery.

Health

People will be surprised if they get to know that their body contains ten times more microorganisms than the body cells. These microorganisms are useful for the body and perform various useful functions, for example *E. coli* (specie of bacteria) resides in the intestine and releases such components which help in the digestion of the food. If microorganisms help in performing different body functions, then they also take something from the body that is they take nutrients from the body. One purpose of bacteria in the body is to fight against those harmful bacteria which can cause diseases. For example, there is also a bacterium in the gut which helps in synthesizing the vitamins like biotin, vitamin K and folic acid.

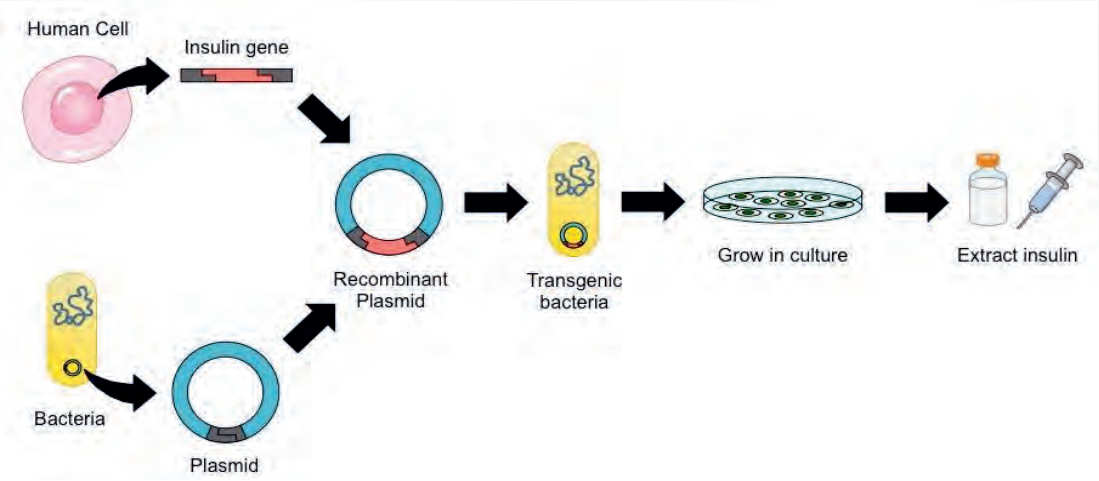


Figure 2.35. Gene transfer to produce human insulin in bacteria. Source. BioNInja

Biotechnology

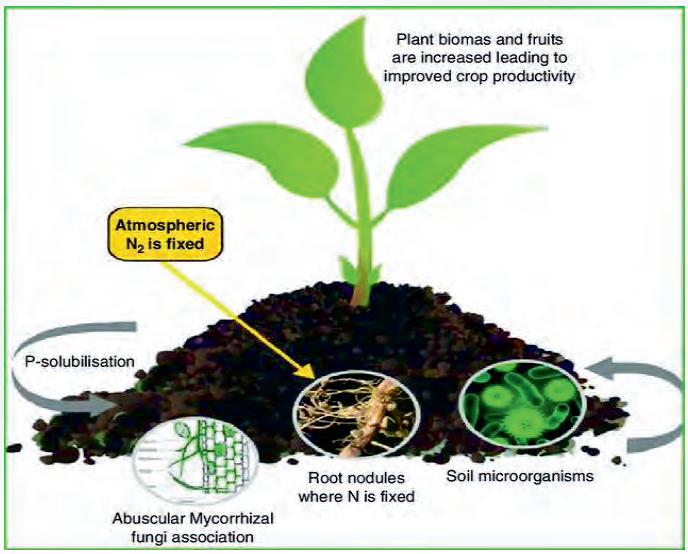
Biotechnology is one field which has made use of microorganisms most. By using the techniques of biotechnology, scientists have succeeded in developing human insulin, growth hormones and other useful components of the body.

Biotechnological processes use microorganisms for the drug delivery in the form of vectors and plasmids. Microorganisms have provided many beneficial things to agriculture as they are responsible for increasing the fertility of the soil. Due to this, the production of the plants increases and economy becomes strong.

Self-Assessment Questions

- List all the Ethiopian traditional fermented food, beverages, and condiments.
- Which are the main types of microorganisms in Ethiopian food fermentation?
- What microorganisms are important in the spoilage of foods?
- What are the industrial roles of microorganisms?

Generally, microorganisms (MOS) have a



big role in, suppression of soil-borne pathogens, recycling and increased availability of plant nutrients, degradation of toxicants including pesticides, Production of antibiotics and other bioactive compounds, Production of simple organic molecules for plant uptake. In addition, MOS are essential in alleviating complexation of heavy metals to limit plant uptake, solubilization of insoluble nutrient sources(Figure 2.23), and Production of polysaccharides to improve soil aggregation

Bacteria are found in every ecosystem they are pretty well everywhere around you and everywhere inside you as well! There are ten bacterial cells inside you for every one of your own cells. Most of these are found in the alimentary canal.

The role of bacteria in recycling minerals through ecosystems

Many bacteria are decomposers. When organisms die, these bacteria break down the complex molecules that are found in the bodies of the dead organisms into much simpler molecules. The bacteria use some of these for their own metabolism, but in the process, they release some minerals (Figure 2. 24), in various forms, into the environment.

Almost, 90% all living organisms are made up of C, O, N and H and these substance are limited in their availability. Thus in order for life to continue the substances should be recycled. This is done by decomposers.

The carbon cycle

All organisms are composed of organic molecules such as proteins, lipids, and carbohydrates. The carbon travels through the food chain as primary producers are eaten by primary consumers, which are then eaten by secondary consumers. Decomposers then use the remains of primary producers and consumers.

Carbon Fixation

A fundamental aspect of the carbon cycle is carbon fixation, the defining characteristic of primary producers. Without primary producers, no other organisms, including humans, could exist.

Respiration and Fermentation When heterotrophs consume organic material, they

break it down using respiration and/or fermentation to release the energy, which is captured to make ATP. The processes usually make CO_2. The type of organic material helps dictate which species degrade it. A wide variety of organisms use sugars, amino acids, and proteins as energy sources, but rapidly multiplying bacteria often the O_2 supply has a strong influence on the carbon cycle. Not only does O_2 allow degradation of certain compounds such as lignin, it also helps determine the types of carbon-containing gases produced. When organic matter is degraded aerobically, a great deal of CO_2 is produced (Figure 2.37). When the O_2 level is low, however, as is the case in marshes, swamps, and manure piles, the degradation is incomplete, generating some CO_2 and a variety of other products.

Methanogenesis and Methane Oxidation

In anaerobic environments, CO_2 is used by methanogens. These archaea obtain energy by oxidizing hydrogen gas, using CO_2 as a terminal electron acceptor, generating methane (CH_4). Methane that enters the atmosphere is oxidized by ultraviolet light and chemical ions, forming carbon monoxide (CO) and CO_2. A group of microorganisms called methylotrophs can use methane as an energy source, oxidizing it to produce CO_2.

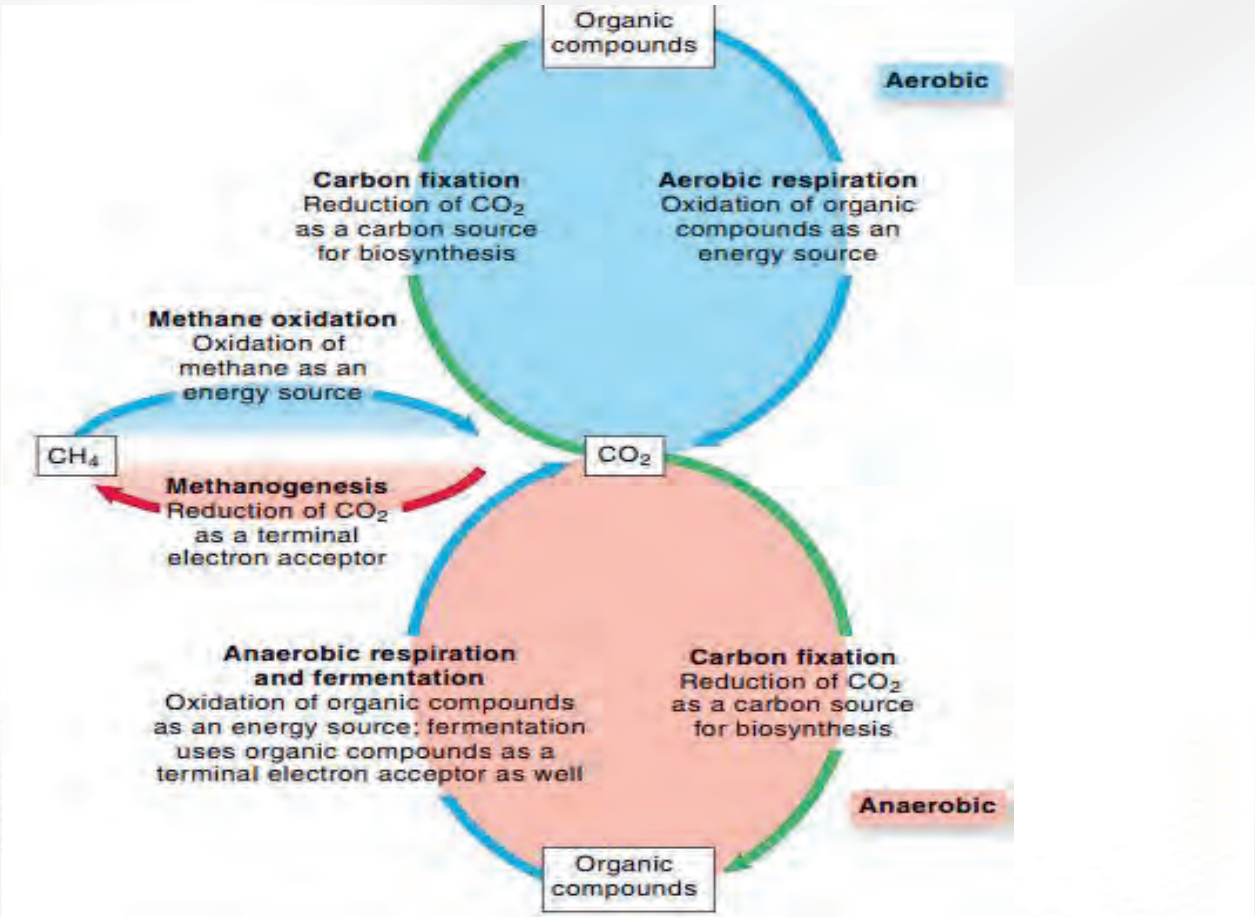


Figure 2.37. The carbon cycle

The Nitrogen cycle

Root nodules are found on the roots of plants, primarily legumes, which form a symbiosis with nitrogen-fixing (Figure 2.38) bacteria. Under nitrogen-limiting conditions, capable plants form a symbiotic relationship with a host-specific strain of bacteria known as rhizobia. Nitrogen fixation in the nodule is very oxygen sensitive.

Key Processes and Prokaryotes in the Nitrogen Cycle

Processes	Example organisms
Nitrification ($NH_4^+ \rightarrow NO_3^-$)	
$NH_4^+ \rightarrow NO_2^-$	*Nitrosomonas*
$NO_2^- \rightarrow NO_3^-$	*Nitrobacter*
Denitrification ($NO_3^- \rightarrow N_2$)	*Bacillus, Paracoccus, Pseudomonas*
N_2 Fixation ($N_2 + 8\,H \rightarrow NH_3 + H_2$)	
Free-living	
Aerobic	*Azotobacter* Cyanobacteria
Anaerobic	*Clostridium*, purple and green phototrophic bacteria *Methanobacterium (Archaea)*
Symbiotic	*Rhizobium Bradyrhizobium Frankia*
Ammonification (organic-N $\rightarrow NH_4^+$)	Many organisms can do this
Anammox ($NO_2^- + NH_3 \rightarrow 2\,N_2$)	*Brocadia*

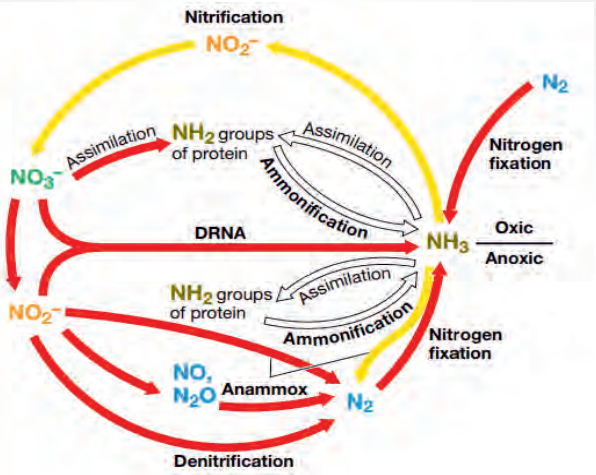


Figure 2.38. The nitrogen cycle

The sulfur cycle

Sulfur is found in fewer types of organic molecules than nitrogen, but it is found in many proteins. Figure 2.39 shows the bacteria involved in the sulfur cycle and the roles they play.

Key Processes and Prokaryotes in the Sulfur Cycle

Process	Organisms
Sulfide/sulfur oxidation ($H_2S \rightarrow S^0 \rightarrow SO_4^{2-}$)	
Aerobic	Sulfur chemolithotrophs (*Thiobacillus, Beggiatoa*, many others)
Anaerobic	Purple and green phototrophic bacteria, some chemolithotrophs
Sulfate reduction (anaerobic) ($SO_4^{2-} \rightarrow H_2S$)	*Desulfovibrio, Desulfobacter Archaeoglobus (Archaea)*
Sulfur reduction (anaerobic) ($S^0 \rightarrow H_2S$)	*Desulfuromonas*, many hyperthermophilic *Archaea*
Sulfur disproportionation ($S_2O_3^{2-} \rightarrow H_2S + SO_4^{2-}$)	*Desulfovibrio*, and others
Organic sulfur compound oxidation or reduction ($CH_3SH \rightarrow CO_2 + H_2S$) (DMSO $\rightarrow$ DMS)	Many organisms can do this
Desulfurylation (organic-S $\rightarrow H_2S$)	Many organisms can do this

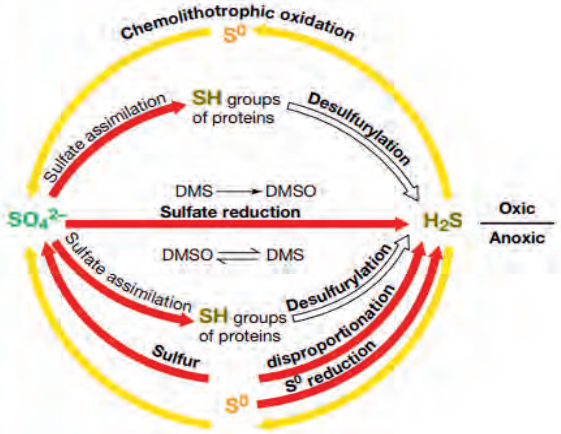


Figure 2.39. The sulfur cycle

The phosphorus cycle

Phosphorus (P) occurs in soils as both organic and inorganic forms (Figure 2.40). Phosphorus can be found dissolved in the soil solution in very low amounts or associated with soil minerals or organic materials. The relative amounts of each form of phosphorus vary greatly among soils, with the total amount of P in a clayey-textured soil being up to ten times greater than in a sandy soil.

Organic P in soils. A large number of compounds make up the organic P in soils, with the majority being of microbial origin. Organic P is held very tightly and is generally not available for plant uptake until the organic materials are decomposed and the phosphorus released via the mineralization process. Mineralization is carried out by microbes, and as with nitrogen, the rate of P release is affected by factors such as soil moisture, composition of the organic material, oxygen concentration and pH.

Inorganic P in soils. The concentration of inorganic P (orthophosphates) in the soil solution at any given time is very small, amounting to less than 1 lb. /A. Phosphorus in the inorganic form occurs mostly as aluminum, iron or calcium compounds.

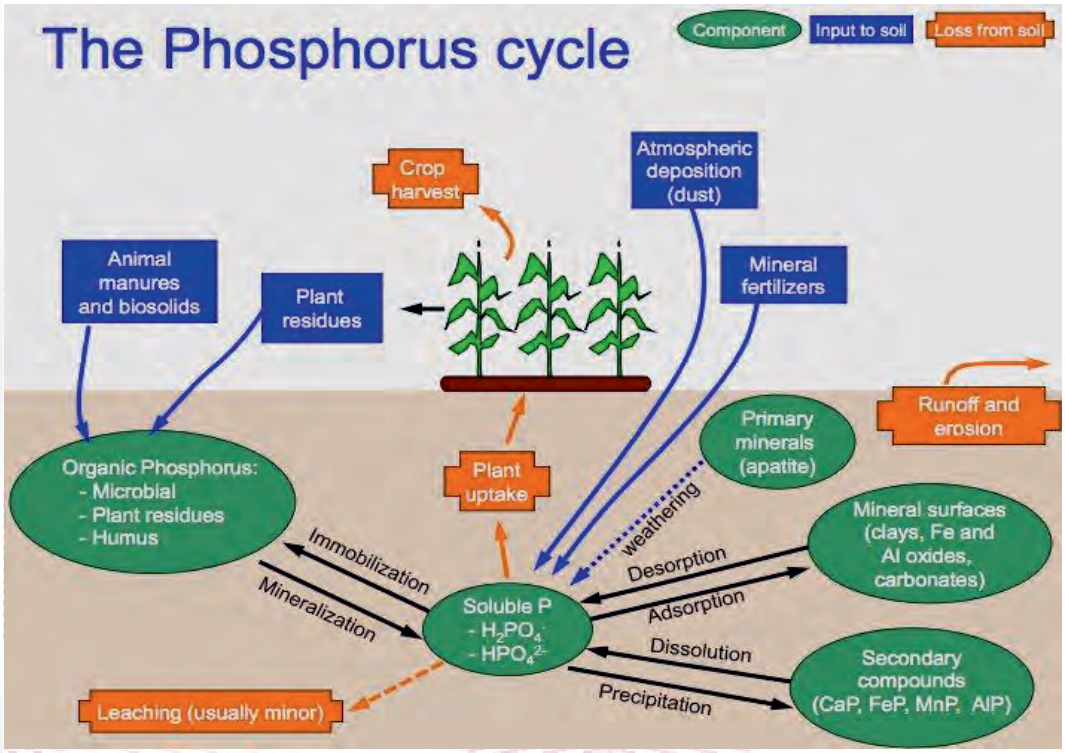


Figure 2.40. The phosphorus cycle

2.9. Controlling microorganisms

Sterilization is defined as a process by which an article, surface, or medium is freed of all living microorganisms either in the vegetative or in the spore state. Any material that has been subjected to this process is said to be *sterile*. These terms should be used only in the absolute sense. An object cannot be slightly sterile or almost sterile; it is either sterile or not sterile. Although most sterilization is performed with a physical agent, such as heat, a few chemicals called *sterilants* can be classified as sterilizing

agents because of their ability to destroy spores.

A *germicide,* also called a *microbicide,* is any chemical agent that kills pathogenic microorganisms. A germicide can be used on inanimate (nonliving) materials or on living tissue, but it ordinarily cannot kill resistant microbial cells. Any physical or chemical agent that kills "germs" is said to have *germicidal* properties.

Disinfection refers to the use of a chemical agent that destroys or removes all pathogenic organisms or organisms capable of giving rise to infection. This process destroys vegetative pathogens but not bacterial endospores. It is important to note that disinfectants are normally used only on inanimate objects because they can be toxic to human and other animal tissue, when used in higher concentrations. Disinfection processes also remove the harmful products of microorganisms (toxins) from materials. Examples of disinfection include

a). applying a solution of 5% bleach to examining table,

(b) Boiling food utensils used by a sick person, and

(c) Immersing thermometers in an isopropyl alcohol solution between uses.

Chemical agents called antiseptics are applied directly to the exposed body surfaces (e.g., skin and mucous membranes), wounds, and surgical incisions to destroy or inhibit vegetative pathogens.

Examples of antisepsis include:

(a) Preparing the skin before surgical incisions with iodine compounds,

(b) Swabbing an open root canal with hydrogen peroxide, and

(c) Ordinary hand washing with a germicidal soap.

Sanitization is any cleansing technique that mechanically removes microorganisms (along with food debris) to reduce the level of contaminants. A sanitizer is a compound (e.g., soap or detergent) that is used to perform this task. Cooking utensils, dishes, bottles, cans, and used clothing that have been washed and dried may not be completely free of microbes, but they are considered safe for normal use. Air sanitization with ultraviolet lamps reduces airborne microbes in hospital rooms, veterinary clinics, and laboratory installations.

Preservation is a general term for measures taken to prevent microbecaused spoilage of susceptible products (pharmaceuticals, foods).

Decontamination is the removal or count reduction of microorganisms contaminating an object. The objective of aseptic measures

and techniques is to prevent microbial contamination of materials or wounds.In antiseptic measures, chemical agents are used to fight pathogens in or on living tissue, for example in a wound.

Physical Methods of Sterilization and Disinfection

Heat

The application of heat is a simple, cheap and effective method of killing pathogens. Methods of heat application vary according to the specific application.

Pasteurization. This is the antimicrobial treatment used for foods in liquid form (milk):

— Low-temperature pasteurization: 61.5 ^{0}C, 30 minutes; 71^{0}C, 15 seconds.

— High-temperature pasteurization: brief (seconds) of exposure to 80–85^{0}C in continuous operation.

— Uperization: heating to 150^{0}C for 2.5 seconds in a pressurized container using steam injection.

Disinfection. Application of temperatures below what would be required for sterilization. Important: boiling medical instruments, needles, syringes, etc. does not constitute sterilization! Many bacterial spores are not killed by this method.

Dry heat sterilization. Sterilization by dry heat includes sterilization by

(a) Flaming : Sterilization of inoculating loop or wire, the tip of forceps, searing spatulas, etc., is carried out by holding them in the flame of the Bunsen burner till they become red hot.

(b) Incineration: Incineration is an excellent method for safely destroying infective materials by burning them to ashes. It has many uses:

■ Incinerators are used to carry out this process and are regularly employed in hospitals and research labs to destroy hospital and laboratory wastes.

■The method is used for complete destruction and disposal of infectious material, such as syringes, needles, culture material, dressings, bandages, bedding, animal carcasses, and pathology samples.

■This method is fast and effective for most hospital wastes, but not for metals and heat-resistant glass materials.

(c) Hot air oven: Sterilization by hot-air oven requires exposure to 160–180°C for 2 hours and 30 minutes, which ensures thorough heating of the objects and destruction of spores.

Moist heat sterilization. Autoclaves charged with saturated, pressurized steam are used for this purpose:

— 121^{0}C, 15 minutes, one atmosphere of pressure (total: 202 kPa).

— 134^{0}C, three minutes, two atmospheres of pressure (total: 303 kPa).

In practical operation, the heating and equalibriating heat up and equalizing times must be added to these, i.e., the time required for the temperature in the most inaccessible part of the item(s) to be sterilized to reach sterilization level. When sterilizing liquids, a cooling time is also required to avoid boiling point retardation and soon."

Intermittent sterilization

Certain heat-labile substances (e.g., serum, sugar, egg, etc.) that cannot withstand the high temperature of the autoclave can be sterilized by a process of intermittent sterilization, known as tyndallization.

Tyndallization is carried out over a period of 3 days and requires a chamber to hold the materials and a reservoir for boiling water. Items to be sterilized are kept in the chamber and are exposed to free-flowing steam at 100°C for 20 minutes, for each of the three consecutive days.

2.10. Bacterial Isolation techniques

Microorganisms (bateria or fungi) can be isolated from food, soil, water or from other materials. For bacterial/fungal isolation, the soil (food) samples are collected from the desired sites (Figure 2.41). Microorganism are separated on artificial media by serial dilution method. Each of the isolates are purified on new media and experimented for the morphological characteristic like shape, gram nature and arrangement of cells, motility etc. Enzymatic activities were tested by biochemical characterization. Finally, molecular techniques are used for further identifications.

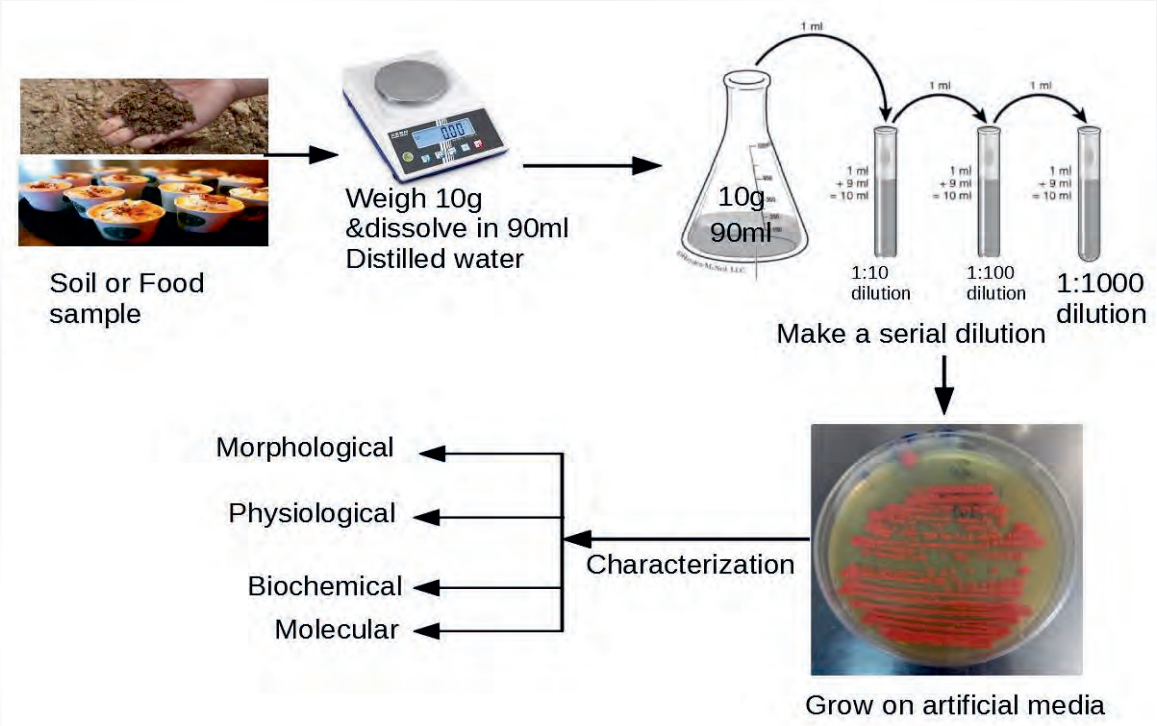


Figure 2.41. Technique for microbial isolation from environmental or food samples

2.11. Renowned Microbiologists in Ethiopia

Activity 2. 10

Search for, study the works of a renowned microbiologist/parasitologist in Ethiopia, and evaluate the contribution of his/her research to the world of science.

Unit summary

Microorganisms are very diverse and are found in all three domains of life: Archaea, Bacteria, and Eukarya. Archaea and bacteria are classified as prokaryotes because they lack a cellular nucleus. Archaea differ from bacteria in evolutionary history, genetics, metabolic pathways, and cell wall and membrane composition. Archaea inhabit nearly every environment on earth, but no archaea have been identified as human pathogens. Eukaryotes studied in microbiology include algae, protozoa, fungi, and helminths. Algae are plant-like organisms that can be either unicellular or multicellular, and derive energy via photosynthesis. Protozoa are unicellular organisms with complex cell structures; most are motile. Microscopic fungi include

molds and yeasts. Helminths are multicellular parasitic worms. They are included in the field of microbiology because their eggs and larvae are often microscopic. Viruses are acellular microorganisms that require a host to reproduce. The field of microbiology is extremely broad. Microbiologists typically specialize in one of many subfields, but all health professionals need a solid foundation in clinical microbiology

Unit review questions

I. Choose the correct answer from A to D for the following equations.

1. Which of the following is present in both gram-positive and gram negative cell walls?

   a. an outer membrane b. peptidoglycan c. teichoic acid d. lipopolysaccharides

2. Bacterial endospore function in,

   Reproduction b. protein synthesis c. survival d. storage

3. Bacterial arrangement in packets of eight cells is described as a----------.

   a. micrococcus b. tetrad c. diplococcus d. sarcina

4. Archaea differ from bacteria on the basis of,

   a. structure of envelope b. size c. the archaea having a nucleus d. type of locomotor structures

5. Which of the following terms refers to a prokaryotic cell that is comma shaped?

   a. Coccus b. coccobacilli c. vibrio d. spirillum

6. Which bacterial structures are important for adherence to surfaces? (Select all that apply.)

   a. endospores b. cell walls c. fimbriae d. capsules e. flagella

II. Fill in the Blank Spaces

1. The bacterium that causes syphilis is called _____.
2. Bacteria in the genus Rhodospirillum that use hydrogen for oxidation and fix nitrogen are _____ bacteria.

3. Streptococcus is the _____ of bacteria that is responsible for many human diseases.

4. The length of the branches of the evolutionary tree characterizes the evolutionary _____ between organisms.

5. The deeply branching bacteria are thought to be the form of life closest to the last universal _____ _____.

6. Nonseptate hyphae are also called _____.

7. Unicellular fungi are called _____

8. Some fungi have proven medically useful because they can be used to produce _____.

9. A virus that infects a bacterium is called a/an _____.

10. A/an _____ virus possesses characteristics of both a polyhedral and helical virus

11. A virus containing only nucleic acid and a capsid is called a/an _____ virus or _____ virus.

12. Viruses can be diagnosed and observed using a(n) _____ microscope.

III. Short Answer

1. Which genera of fungi are common dermatophytes (fungi that cause skin infections)?

2. What is a dikaryotic cell?

3. Discuss the geometric differences among helical, polyhedral, and complex viruses.

4. Briefly explain the various methods of culturing viruses.

5. Does a prion replicate? Explain.

6. What are kinetoplastids?

7. Aside from a risk of birth defects, what other effect might a toxoplasmosis infection have?

Unit 3: Energy Transformation

UNIT 3. ENERGY TRANSFORMATION

Unit learning outcomes

At the end of this unit, student will be able to:

- Discuss the process of energy transformation in cells .
- Summarize the process of photosynthesis using chemical equation.
- Analyze an absorption spectra of chlorophyll a and chlorophyll b using graph.
- Discuss the mechanism as to how CO_2 is fixed in C_3,C_4 plants, and CAM Plants.
- Justify the reason why the rate of photorespiration is less in C4 plants as compared to C3 plants.
- Demonstrate whether or not organic molecules (such as starch) present in leaves.
- Discuss how energy is harvested during aerobic respiration.
- Differentiate between substrate-level phosphorylation and oxidative phosphorylation
- Show the mechanism electron transport system in mitochondria.
- Discuss the significances of fermentation by microorganisms in our daily life.
- Apply the concept of cellular respiration to calculate amount of energy yield from a given molecule of glucose.
- Justify how energy transformations in cells contribute for the maintenance CO_2 and O_2 balance in the atomosphere.
- Appreciate the mechanism of energy transformation in cells.

Appreciate the role of photosynthesis and cellular respiration for continuity of life

Overview

Living cells are in constant activity. Macromolecules are assembled and broken down, substances are transported across cell membranes, and genetic instructions are transmitted. All of these cellular activities require energy. Living organisms are unique in that they can extract energy from their environments and use it to carry out life activities such as movement, growth and development, and reproduction. But the basic question is how living organisms or, their cells extract energy from their environments, and how cells use this energy to synthesize macromolecules? The answers to these questions lie in the enzyme-mediated chemical reactions that take place in living

matter (metabolism). In metabolism, series of chemical reactions are taking place in the cells of organisms. These reactions may aid in the transformations of energy from one form to another in cells.

3.1. Energy

By the end of this section, the student will be able to:

- Define cellular metabolism.
- Explain anabolic and catabolic pathways in cellular metabolism.

Metabolism is the sum of chemical reactions that takes place within each cell of an organism. The chemical reactions enable cells to produce energy for vital processes and also synthesize new organic materials. Broadly, these reactions can be divided into catabolic reactions that convert nutrients to energy and anabolic reactions that lead to the synthesis of larger biomolecules.

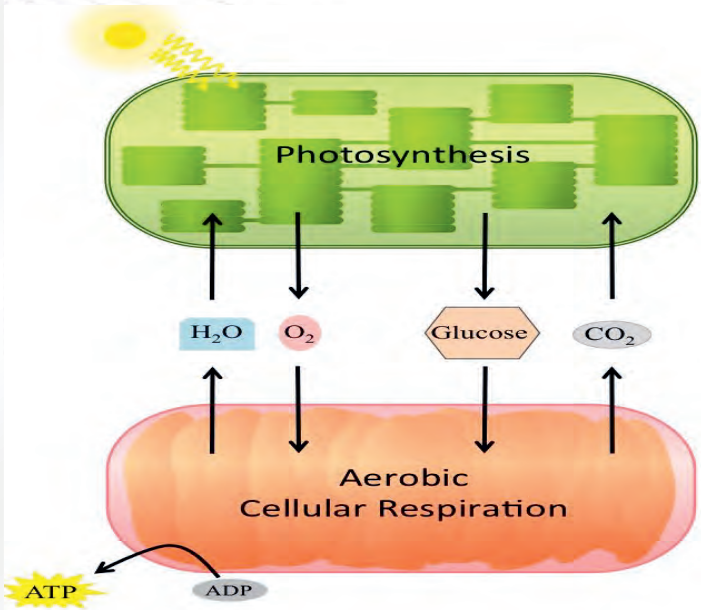
Anabolism is the set of reactions involved in the synthesis of complex molecules, starting from the small molecules inside the cells of an organism. Anabolic reactions help in the building of macromolecules like proteins, nucleic acids, and polysaccharides.

Catabolism is the set of reactions involved in the breakdown of complex molecules like proteins, gacids, glucose, and fatty acids, respectively. It is also the breakdown of monomers into carbon

The **main difference** between anabolism and catabolism is that anabolism is a constructive process whereas catabolism is a descrctive process.

Table 3.1. Comparison of anabolic and catabolic pathways

No.	Anabolism	Catabolism
1.	It is the constructive phase of metabolism.	It is the destructive phase of metabolism.
2.	It is the process whereby simpler substances are joined together to form complex macromolecules.	It is the process whereby complex macromolecules are broken down to form simpler substances or monomers.
3.	The process requires energy to construct substances.	The process releases energy as a result of the breakdown of molecules.
4.	It is an endergonic (energy-absorbing) reaction.	It is an exergonic (energy-releasing) reaction.
5.	It occurs during photosynthesis.	It occurs during cellular respiration.



Self-questioning

? What does metabolism mean in a cellular sense?

? How are anabolism and catabolism differ?

Figure 3.1. Metabolic pathways

3.2. Photosynthesis

By the end of this section, you will be able to:

Define photosynthesis.

Explain the process of dark and light reaction of photosynthesis.

Describe the external and internal structure of a leaf.

Describe the different chlorophyll pigments involved in the absorption of light energy.

Analyze an absorption spectra of the chlorophyll pigments from the graph.

Explain the the roles of grana and and stroma in the process of photosynthesis.

Describe cyclic and non-cyclic photophosphorylation.

Show an absorption spectra of chlorophyll a and chlorophyll b using graph.

Explain the process of Calvin cycle.

Compare cyclic and non-cyclic photophosphorylation.

Differentiate between C3 , C4 plants, and CAM Plants.

Justify the reason why the rate of photorespiration is less in C4 plants as compared to C3 plants.

Summarize the process of photosynthesis using chemical equation.

Conduct an experiment to show the release of energy during photosynthesis.

Conduct an experiment to show the presence of starch in green leaves.

Explain the significances of photosynthesis.

Photosynthesis is a series of chemical reactions that use light energy to assemble CO2 into glucose (C6H12O6) and other carbohydrates. The plant uses water in the process and releases oxygen gas (O2) as a byproduct. The reactions of photosynthesis are summarized as follows:

Self-questioning

- How is an autotroph different from a heterotroph?
- Write the chemical equation of photosynthesis.
- Why is photosynthesis

$$6\,CO_2 + 12\,H_2O \xrightarrow[\text{Chlorophyll}]{\text{Light energy}} C_6H_{12}O_6 + 6\,O_2 + 6\,H_2O$$

Carbon dioxide — Water — Glucose — Oxygen — Water

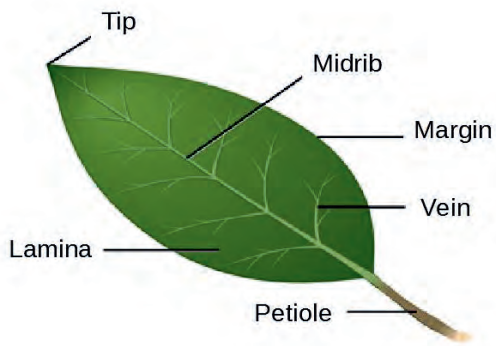
This process provides not only food for the plant but also the energy, raw materials, and O_2 that are used to support most **heterotrophs**. Oxygen is a byproduct of photosynthesis. Furthermore, photosynthesis is important because it is the number one source of oxygen in the atmosphere; it contributes to the carbon cycle among the earth, the oceans, plants and animals; it contributes to the symbiotic relationship among plants, humans and animals; it directly or indirectly affects most living things on earth; it serves as the primary energy process for plants. Plants, multicellular algae, some protists, Cyanobacteria, and Purple sulfur bacteria are Photoautotrophs.

External and Internal Structure of the Leaf

The outer leaf layer is known as the epidermis. The epidermis secretes a waxy coating called the cuticle that helps the plant retain water. A leaf has three main parts– Leaf base, leaf lamina, and petiole (Figure 3.2). Epidermis is a continuous layer on the outside of the plant, one cell thick, that provides protection .In stems and leaves it is covered with a waxy cuticle

which is waterproof and helps to protect the organ from drying out and from infection. In leaves, it also has pores called stomata which allow entry of carbon dioxide for photosynthesis. The mesophyll is made up of specialised parenchyma cells found between the lower and upper epidermis of the leaf. They are specialised for photosynthesis and therefore contain chloroplasts. They are of two types, palisade mesophyll and spongy mesophyll. Spongy mesophyll is so-called because in three

dimensions it is spongy in appearance, because it has many large air spaces between the cells. Palisade mesophyll cells are near the upper surface of the leaf where they receive more sunlight. They therefore contain more chloroplasts than spongy mesophyll cells (Figure 3.3).



A). External Structure of a Leaf

*Explain each external part of a leaf

*Most leaves are flat. What is the advantage of flatness for the plant?

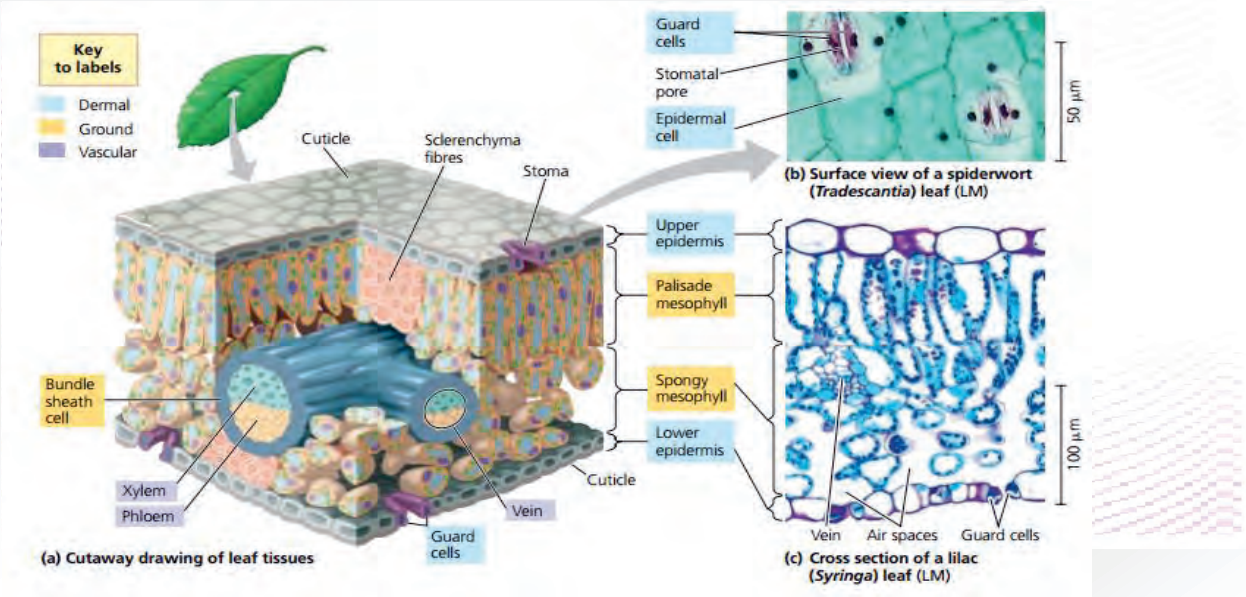
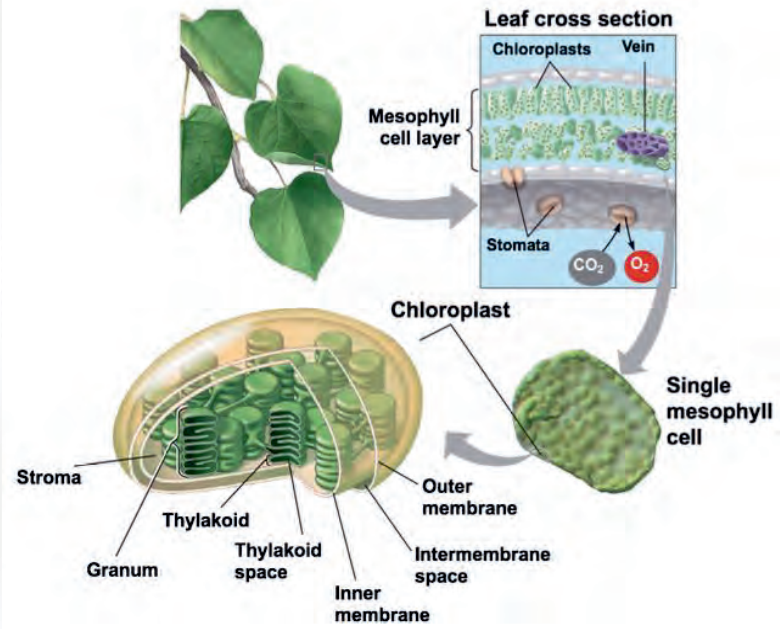


Figure 3.3. Internal structure of leaf

The site of photosynthesis

In plants, the highest density of chloroplasts is found in the mesophyll cells of leaves. A double membrane surrounds chloroplast, where the outer membrane faces the cytoplasm of the plant cell on one side and the intermembrane space of the chloroplast on the other.

The inner membrane separates the narrow intermembrane space from the aqueous interior of the chloroplast, called the **stroma**. The stroma is a fluid-filled matrix where the light-independent stage of photosynthesis takes place. Within the stroma are a number of other structures such as search grains.Within the stroma, another set of membranes form disk-shaped compartments known as **thylakoids (**Figure 3.4**)**. The interior of a thylakoid is called the **thylakoid lumen**. In most plant species, the thylakoids are interconnected to form stacks called **grana**. The grana are stacks of up to 100 disc-like structu res called thylakoids where the light-dependent stage of photosynthesis takes place. Within the thylakoids is the photosynthetic pigment called chlorophyll. Some thylakoids have tubular extensions that join up with thylakoids in adjacent grana. These are called imergranal lamellae.



Self-questioning

- Where do you think is the site of photosynthesis in Plants?

Figure 3.4. The structure of a chloroplast and its location within a plant cell and leaf

3.2.1. Photosynthetic pigments

Self-questioning

1. What are the main components of sunlight?
2. How does having multiple types of pigments benefit plants?

Photosynthetic cells contain special pigments that absorb light energy. Different pigments respond to different wavelengths of visible light. Pigments are chemical compounds which reflect only certain wavelengths of visible light. This makes them appear "colorful". Flowers, corals, and even animal skin contain pigments which give them their particular colors. More important than their reflection of light is the ability of pigments to **absorb** certain wavelengths.

Because they interact with light to absorb only certain wavelengths, pigments are useful to plants and other **autotrophs.** In plants, algae, and cyanobacteria, pigments are the means by which the energy of sunlight is captured for photosynthesis. However, since each pigment reacts with only a narrow range of the spectrum, there is usually a need to produce several kinds of pigments, each of a different color, to capture more solar energy. There are three basic classes of pigments.

Chlorophylls are greenish pigments which contain a **porphyrin ring**. This ring has the potential to gain or lose electrons easily and whereby providing energized electrons to other molecules. There are several kinds of chlorophyll, which the most important one is **chlorophyll "a".**

It is a green pigment found in all plants, algae, and cyanobacteria. The second kind of **chlorophyll, chlorophyll "b"** occurs only in "green algae" and in plants. The third form of chlorophyll called **chlorophyll "c"**, is found only in the photosynthetic members of the Chromista and dinoflagellates.

Carotenoids are usually red, orange, or yellow pigments, and they include the familiar compound carotene, which gives carrots their color. Carotenoids cannot transfer sunlight energy directly to the photosynthetic pathway, but must pass their absorbed energy to chlorophyll. For this reason, they are called **accessory pigments**. One very visible accessory pigment is **fucoxanthin,** the brown pigment whose colors keep other brown algae as well as the diatoms.

Activity 3. 4

Discuss in a group and write your answer on your notebook if you could expose plants to just one wavelength of light at a time, would a wavelength of 350 nm, 450 nm, or 600 nm produce the highest photosynthetic rate?

Phycobilins are water-soluble pigments, and are, therefore, found in the cytoplasm, or in the stroma of the chloroplast. They occur only in Cyanobacteria and Rhodophyta.

Absorption spectra of photosynthetic pigments

An absorption spectrum is a graph that shows absorption from a spectrophotometer. **Figure 3.5** shows absorption at wavelengths from 400-700 nm by three pigments; ***Chlorophyll a***, ***Chlorophyll b***, and the carotenoids. ***Chlorophyll a*** absorbs violet-blue and reddish orange-red wavelengths. ***Chlorophyll b*** absorbs mostly blue and yellow light. Both ***Chlorophyll a*** and ***Chlorophyll b*** also absorb light of other wavelengths with less intensity. However, none of them absorbs green, so that the leaf looks green because light is reflected to our eyes instead of being absorbed by the leaf. Carotenoids are ubiquitous and essential pigments in photosynthesis. They absorb in the **blue-green region** (Figure 3.5) of the solar spectrum and transfer the absorbed energy to (bacterio) chlorophylls, and thereby expanding the wavelength range of light that is able to drive photosynthesis. Only absorbed light (largely blue and red) is useful in photosynthesis.

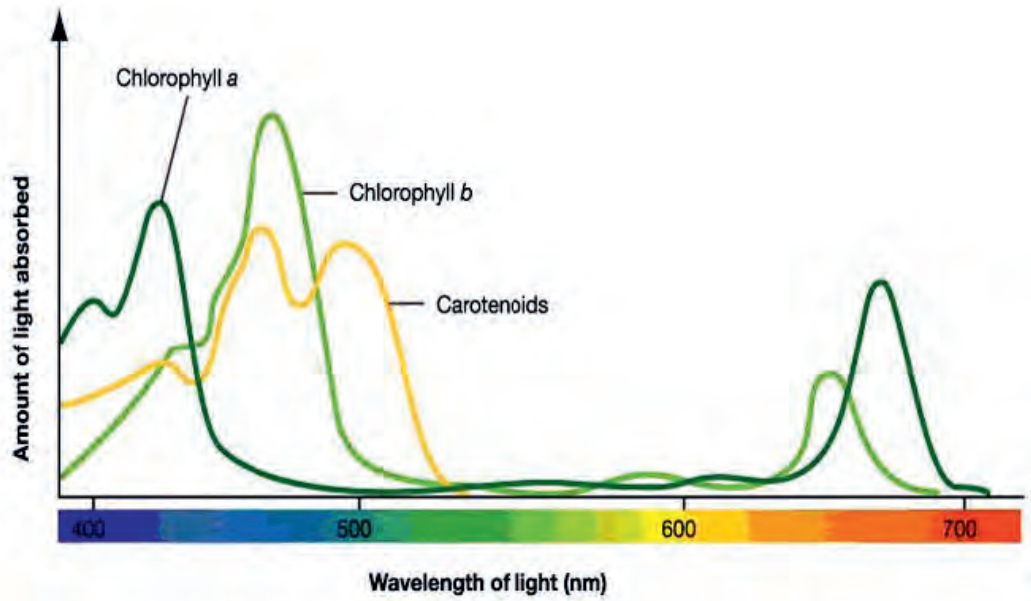


Figure 3.5. Absorption spectrum of *Chlorophyll a*, *Chlorophyll b*, and carotenoids

Practical activity - paper chromatography

3.2.2. Light-dependent and light-independent reactions

Inside a chloroplast, photosynthesis occurs in two stages: the light-dependent reactions and the light-independent (or Calvin Cycle) reactions.

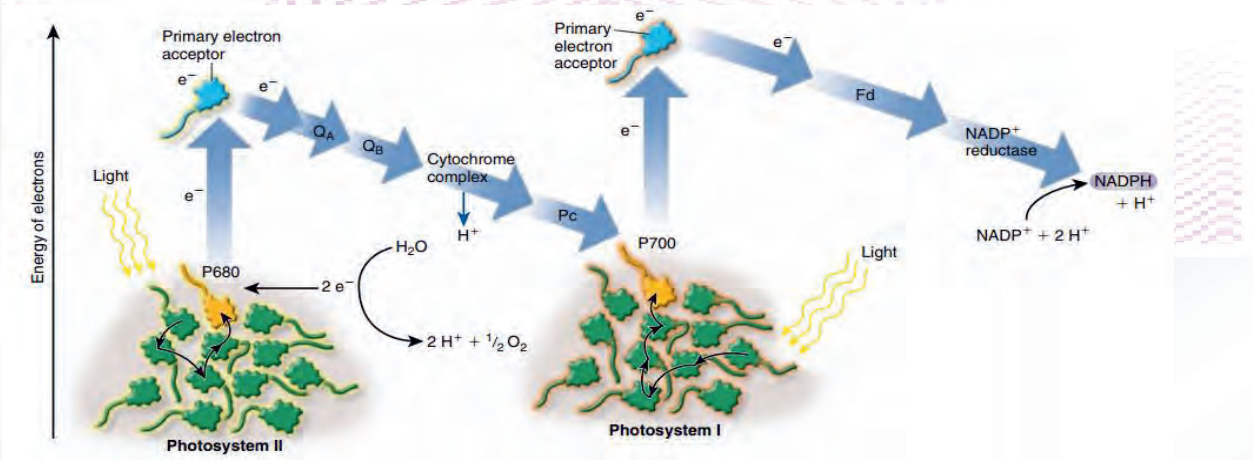
Light-Dependent Reactions(cyclic and non-cyclic photophosphorylation)

The light reactions are the steps of photosynthesis that convert solar energy to chemical energy. Water is split, providing a source of electrons and protons (hydrogen ions, H+) and giving off O_2 as a by-product (Figure 3.6). Light absorbed by chlorophyll drives a transfer of the electrons and hydrogen ions from water to an acceptor called $NADP^+$ (nicotinamide adenine dinucleotide phosphate), where they are temporarily stored. (The electron acceptor NADP + is first cousin to NAD^+, which functions as an electron carrier in cellular respiration; the two molecules differ only by the presence of an extra phosphate group in the NADP + molecule.) The light reactions use solar energy to reduce NADP + to NADPH by adding a pair of electrons along with an H^+. The light reactions also generate do not produce sugar.

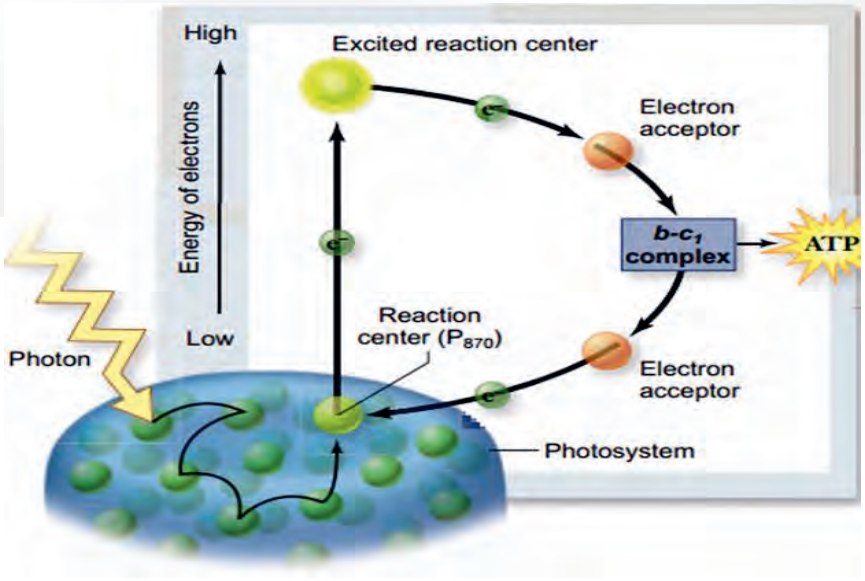
ATP, using chemiosmosis to power the addition of a phosphate group to ADP, a process called photophosphorylation. Thus, light energy is initially converted to chemical energy in the form of two compounds: NADPH and ATP. NADPH, a source of electrons, acts as "reducing power" that can be passed along to an electron acceptor, reducing it, while ATP is the versatile energy currency of cells. Notice that the light reactions

Self-questioning

- What are the two stages at which photosynthesis occurs?
- What happens in each of the two main stages of photosynthesis?
- Where in the chloroplast does each stage occur?



a). Non-cyclic photophosphorylation



b). cyclic photophosphorylation

Figure 3.6. Light dependent reaction of photosynthesis a) Non-cyclic (b) Cyclic photophosphorylation Comparison of cyclic and non-cyclic photophosphorylation

	Non-cyclic	**Cyclic**
Pathway of electrons	Non-cyclic	Cyclic
First electron donor(source of electrons)	Water	photosystemI(P700)
Last electron acceptor destination of electrons)	NADP	Photosystem I(P700)
Products	Useful:ATP, reduced NADP oxygen (byproduct).	Useful:ATP only
Photosystem involved	I and II	I only

Photosystem I and photosystem II

1. Electrons (e^-) in chlorophyll molecules in photosystem II are excited by the energy in photons of light: they become more energetic. Because of the extra energy, they

escape from the chlorophyll and pass to an electron acceptor (the primary electron acceptor).

2. The conditions created in the chloroplast cause the following reaction to occur:

$$2H2O \rightarrow O2 + 4H^{+} + 4e^{-}$$

This light-dependent splitting of water is called photolysis. The electrons replace those lost from the chlorophyll molecule.

3. The primary electron acceptor passes the electrons to the next molecule in an electron transport chain (plastoquinone or 'Pq'). The electrons then pass along a series of cytochromes (similar to those in the mitochondrial electron transport chain) and finally to plastocyanin (Pc) – the last carrier in the chain. The electrons lose energy as they are passed from one carrier to the next.

4. One of the molecules in the cytochromes complex is a proton (hydrogen ion) pump. As electrons are transferred to and then transferred from this molecule, the energy they lose powers the pump which moves protons from the stroma of the chloroplast to the space inside the thylakoid. This leads to an accumulation of protons inside the thylakoid, which drives the chemiosmotic synthesis of ATP.

5. Electrons in chlorophyll molecules in photosystem I are excited (as this photosystem absorbs photons of light) and escape from the molecule. They are replaced by the electrons that have passed down the electron transport chain from photosystem II.

6. The electrons then pass along a second electron transport chain involving ferredoxin (Fd) and NADP reductase. At the end of this electron transport chain, they can react with protons (hydrogen ions) and NADP in the stroma of the chloroplast to form reduced NADP.

Products of Photosynthesis: In summary, the steps of the light reactions of photosynthesis produce three chemical products: O_2, NADPH, and ATP:

1. O_2 is produced in the thylakoid lumen by the oxidation of water by photosystem II. Two electrons are removed from water, which produces 2 H^{+} and 1/2 O_2. The two electrons are transferred to P680 molecules.

2. NADPH is produced in the stroma using high-energy electrons that start in photosystem II and are boosted a second time in photosystem I. Two high-energy electrons and one H+ are transferred to $NADP^{+}$ to produce NADPH.

3. ATP is produced in the stroma via ATP synthase that uses an H^{+} electrochemical gradient.

3.2.5. Light-Independent Reactions (Calvin cycle)

This is the second step in the mechanism of photosynthesis. The chemical processes of photosynthesis occurring independent of light are called dark reactions. It takes place in the stroma of the chloroplast. The dark reaction is purely enzymatic and it is slower than the light reaction. Dark reaction does not require light . In a dark reaction, the sugars are synthesized from CO_2. The energy-poor CO_2 is fixed to energy-rich carbohydrates using the energy-rich compound, ATP, and the assimilatory power, $NADPH_2$ of light reaction. The process is called carbon fixation or carbon assimilation.

C3 Plants are plants capable of fixing CO_2 into a 3-Carbon sugar called Phosphoglycerate (PGA). The energy from ATP and NADPH energy carriers generated by the photosystems is used to phosphorylate the PGA. In this process, carbon dioxide enters a plant through its stomata, and the enzyme Rubisco fixes carbon into sugar using the Calvin cycle. This fixation of carbon dioxide by Rubisco is the first step of the Calvin cycle. The plants that use this mechanism of carbon fixation are called **C3 plants**. Approximately 95% of plants on the earth are C3 plants. Some of the C3 plant examples are wheat, rye, oats, and orchard grass.

The photosynthesis process can take place only when the stomata on leaves are open. C3 plants exhibit the C3 pathway. It is a three-carbon compound (3-PGA). Here the first carbon compound produced has three carbon atoms hence the name "C3 pathway"(Figure 3.7). The light-independent reactions of the Calvin cycle can be organized into three basic stages: fixation, reduction, and regeneration.

1. Carbon fixation: A molecule of carbon dioxide is combined with a carbon acceptor molecule containing five atoms known as ribulose-1,5-bisphosphate (RuBP). This step gives rise to a compound having six carbon atoms that disintegrate into two molecules of a compound containing three carbons called 3-phosphoglyceric acid (3-PGA). This reaction is catalyzed by the enzyme RuBP carboxylase, or rubisco.

2. Reduction: In the second stage of the Calvin cycle, ATP and NADPH molecules are utilized to change the 3-PGA molecules into a sugar molecule containing three carbon atoms called glyceraldehyde-3-phosphate (G3P). This stage has derived its name from the fact that NADPH donates electrons to a three-carbon intermediate to form **G3P**.

3. **Regeneration:** Some **G3P** molecules form glucose, while others need to be recycled so that they can regenerate the RuBP acceptor. Regeneration needs ATP and involves a complex series of reactions called the "carbohydrate scramble."

In the dark reaction, CO_2 is fixed to carbohydrates and the CO_2 acceptor ribulose-diphosphate is regenerated. In the Calvin cycle, $12NADPH_2$ and 18 ATPs are required to fix $6CO_2$ molecules into one hexose sugar molecule (fructose- 6- phosphate).

C_4 plants: In some plants like maize, sorghum, and sugarcane , the first product of carbondioxide fixation is not the three carbon molecule phosphoglycerate but the four carbon compound oxaloacetic acid. Plants that utlize this pathway are commonly called the C4 or four carbon plants. The oxaloacetic acid is formed when carbondioxide is bound to a compound known as phophoenolpyruvate (PEP) in the mesophyll cell. The oxaloacetic acid is reduced to malic acid or converted to aspartic acid; and the malic acid(aspartic acid) is decarboxylated to yield CO_2 and pyruvic acid in the bundle sheth cell (Figure 3.8). Then, CO_2 enters to Calvin cycle.

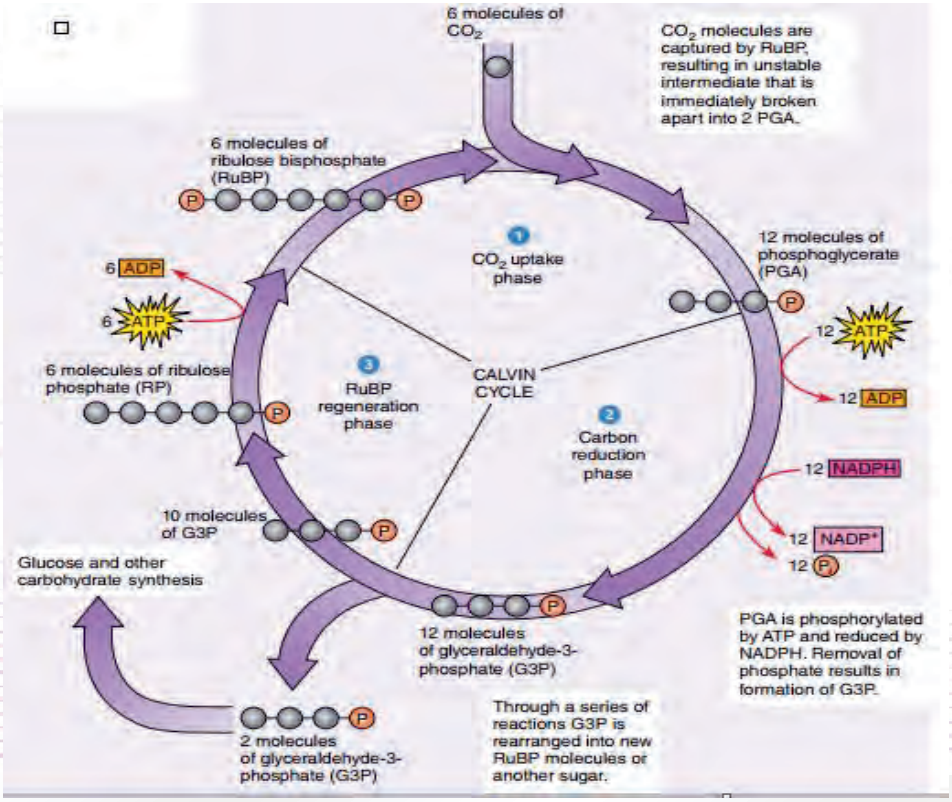


Figure 3.7. Calvincycl (C3 cycle)

The basic C4 cycle consists of four stages:

1. Fixation of CO_2 by the carboxylation of phosphoenol-pyruvate (PEP) in the mesophyll cells to form a C_4 acid.

2. Transport of the C_4 acids to the bundle sheath cells

3. Decarboxylation of the C_4 acids within the bundle sheath cells and generation of CO_2, which is then reduced to carbohydrate via the Calvin cycle.

4. Transport of the C_3 acid (pyruvate or alanine) that is formed by the decarboxylation step back to the mesophyll cell and regeneration of the CO_2 acceptor phosphoenolpyruvate

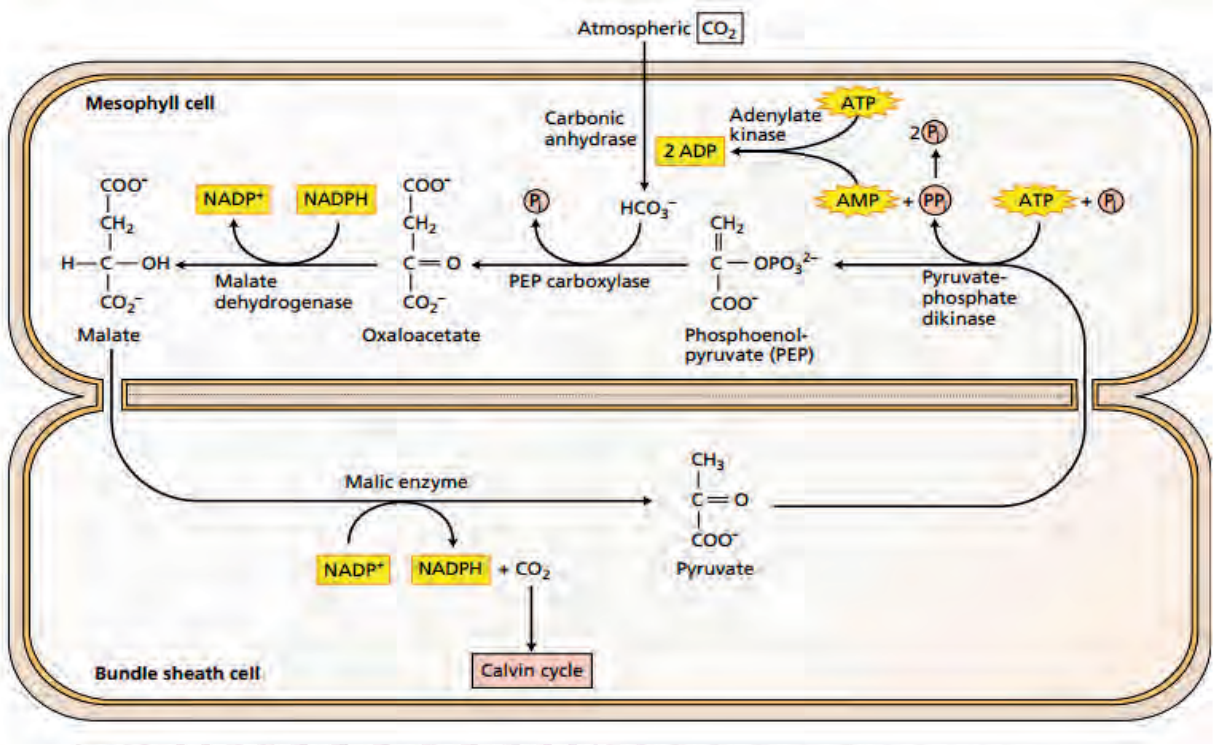


Figure 3.8. The C_4 photosynthetic pathway

CAM (crassulacean acid metabolism)Plants:- The CAM mechanism enables plants to improve water use efficiency. The CAM mechanism is similar in many respects to the C4 cycle. In C_4 plants, formation of the C_4 acids in the mesophyll is spatially separated from decarboxylation of the C_4 acids and from refixation of the resulting CO_2 by the Calvin cycle in the bundle sheath. In CAM plants, formation of the C_4 acids is both temporally and spatially separated.

At night, CO_2 is captured by PEP carboxylase in the cytosol, and the malate that forms from the oxaloacetate product is stored in the vacuole. During the day time, the stored malate is transported to the chloroplast and decarboxylated by NADP-

malic enzyme, the released CO_2 is fixed by the Calvin cycle, and the NADPH is used for converting the decarboxylated triose phosphate product to starch.

CAM plants succulent (water-storing) plants such as cacti achieve their high water use efficiency by opening their stomata during the cool, desert nights and closing them during the hot, dry days. Closing the stomata during the day minimizes water loss, but because H_2O and CO_2 share the same diffusion pathway, CO_2 must then be taken up at night. CO_2 is incorporated via carboxylation of phosphoenolpyruvate to oxaloacetate, which is then reduced to malate. The malate accumulates and is stored in the large vacuoles that are a typical, but not obligatory, anatomic feature of the leaf cells of CAM plants (Figure 3.9).

The accumulation of substantial amounts of malic acid, equivalent to the amount of CO_2 assimilated at night, has long been recognized as a nocturnal acidification of the leaf. With the onset of day, the stomata close, preventing loss of water and further uptake of CO_2. The leaf cells deacidify as the reserves of vacuolar malic acid are consumed. Because the stomata are closed, the internally released CO_2 cannot escape from the leaf and instead is fixed and converted to carbohydrate by the Calvin cycle.

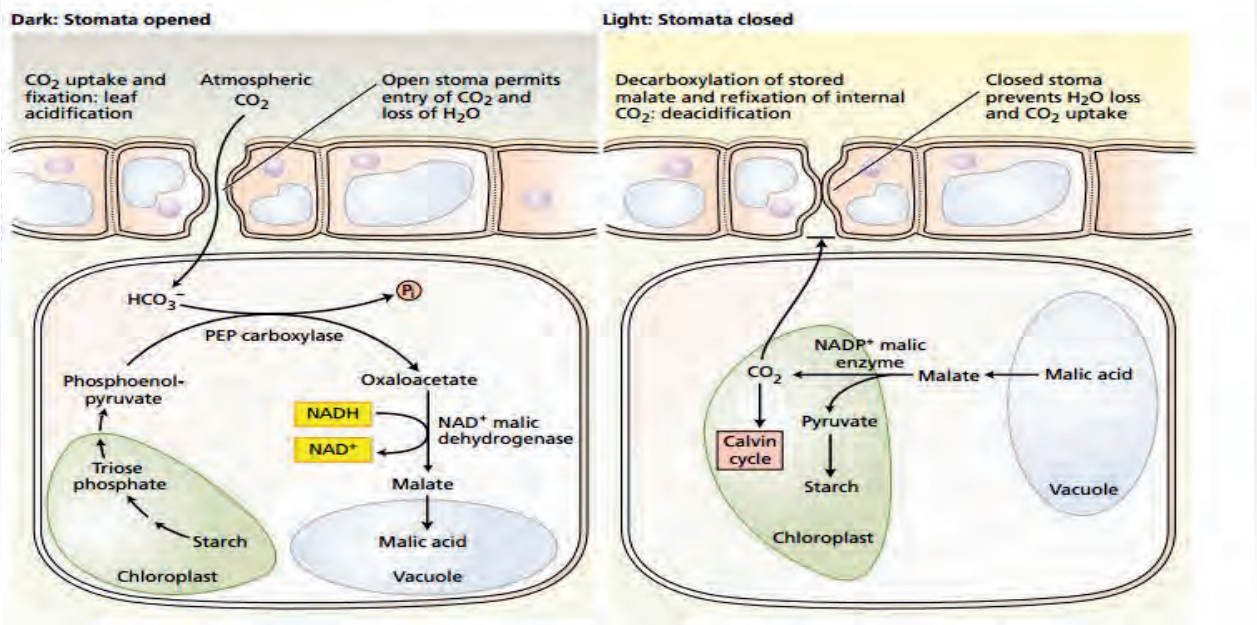


Figure 3.9. CAM cycle

Photorespiration:- Photorespiration is a process which involves oxidation of organic compounds in plants by oxygen in the presence of light. Like ordinary respiration,

this process also releases carbon from organic compounds in the form of CO_2 but does not produce ATP. Thus, apparently it seems to be a wasteful process, but it must have some functions which are still unknown. This process occurs in C3 plants and to some extent in C4. Photorespiratory substrate is glycolate. RuBisco instead of combining with CO_2 it combines with O_2. This type of oxidation of O_2 to RuBP molecule is known as photosynthetic C-oxidation cycle or glycolate pathway or C_2 photorespiratory carbon oxidation cycle. Generally photorespiration is expressed by the term called CO_2 compensation point and it is defined as CO_2 concentration at which rate of uptake will be equal to the rate of photosynthetic respiratory CO_2 released. Photorespiration is common in C3 plants but highly reduced in C4 plants, and absent in CAM plants (Figure 3.10).

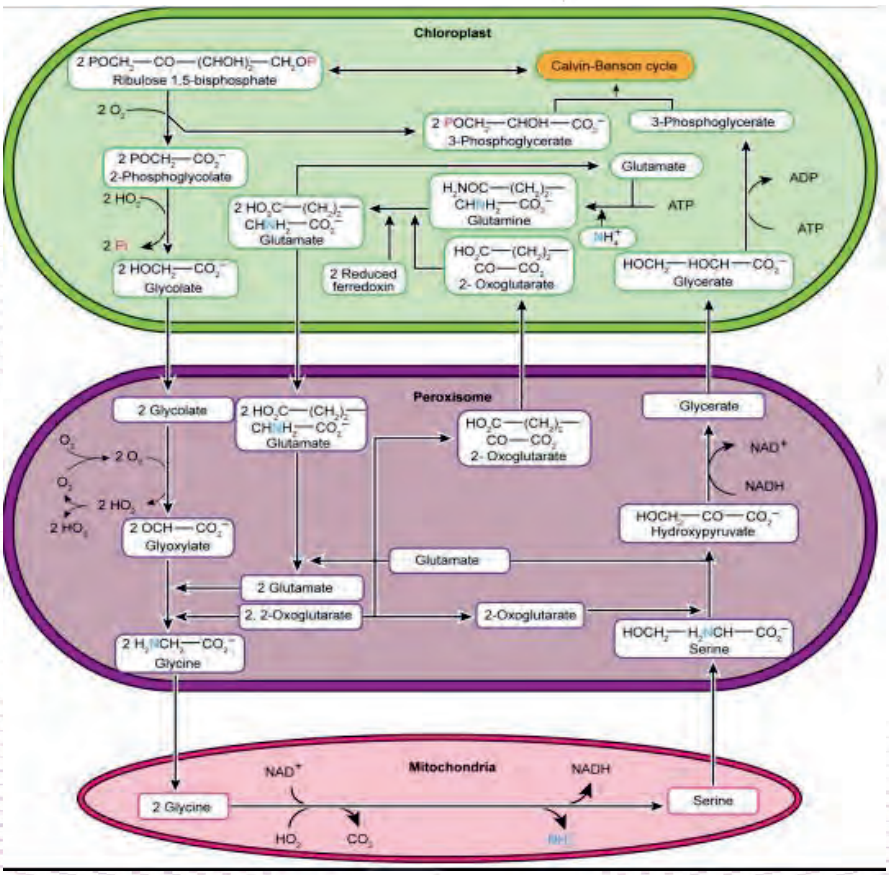


Figure 3.10 The photorespiratory cycle.

Self- questioning

- What is the difference between light-dependent and light-independent reactions?
- Why is the Calvin cycle also called the C3 pathway?
- How does photorespiration counter photosynthesis?
- Describe how a C4 plant minimizes photorespiration.
- How is the CAM pathway like C4 metabolism, and how is it different?

Practical activities 3.3. Testing a leaf for starch

Iodine solution (yellow/brown) and starch (white) form a deep blue colour when they mix. The test for starch, therefore, is to add iodine solution to a leaf to see if it goes blue. However, a living leaf is impermeable to iodine and the chlorophyll in the leaf masks any colour change. So, the leaf has to be treated as follows:

- Heat some water to boiling point in a beaker and then **turn off the Bunsen flame**. Use forceps to dip a leaf in the hot water for about 30 seconds. This kills the cytoplasm, denatures the enzymes and makes the leaf more permeable to iodine solution.
- **Note**: make sure the Bunsen flame is extinguished before starting the next part of the procedure, as ethanol is flammable.
- Push the leaf to the bottom of a test-tube and cover it with ethanol (alcohol). Place the tube in the hot water.
- The alcohol will boil and dissolve out most of the chlorophyll. This makes colour changes with iodine easier to see.
- Pour the green alcohol into a spare beaker, remove the leaf and dip it once more into the hot water to soften it.

- Spread the decolorized leaf flat on a white tile and drop iodine solution on to it. The parts containing starch will turn blue; parts without starch will stain brown or yellow with iodine.

Practical Activity 3.4. Test for Chlorophyll in leaves

Equipment ■ a few spinach leaves	■ rubbing alcohol	■ glass jar
■ filter paper	■ bowl	■ hot water

Method

- Cut up the spinach leaves into very fine pieces.
- Pour some rubbing alcohol into the glass jar and transfer a small quantity of the leaves into the jar.
- Pour some hot water into the bowl and stand the covered jar in it. Stir the leaves in the alcohol from time to time.
- After about an hour, insert a strip of filter paper into the glass jar so that it dips into the green coloured liquid.
- As the liquid rises up the filter paper, draw students' attention to the yellow and orange bands that form on the filter paper.
- **Precaution**

  Alcohol is flammable.

Practical Activity 3.4. To show that oxygen is produced during photosynthesis

in the equation for photosynthesis, we saw that oxygen is given off as a waste product.
When the light intensity is high (bright sunshine), much oxygen is produced.

The oxygen can easily be collected from water since it is not very soluble in water.
This explains why we use an aquatic plant.

Materials and chemicals

- local pond weed
- a 250 cm3 beaker
- a glass funnel
- a test tube
- small stones
- sodium hydrogen carbonate
- water or pond water

Method

1. Place the pond weed in a large beaker filled with about 150 cm3 of pond water. You may add sodium hydrogen carbonate to the water to produce more carbon dioxide.

2. Carefully invert a funnel over the pond weed.

3. Fill a test tube with the same amount of water as in the beaker. Carefully and without allowing any water out of the test tube, invert the test tube over the stem of the funnel.

4. You will need to put some small stones at the bottom of the beaker to support the funnel so that it is raised above the bottom of the beaker. This arrangement allows free water circulation.

5. Place the apparatus in bright sunlight for 3–4 hours.

6. After this period, move the inverted test tube from the inverted funnel stem while still under water. Then cover the test tube with your thumb before removing it from the beaker.

7. Remove your thumb from the test tube mouth and quickly plunge a glowing splint into the test tube.

Activity questions

1. What did you observe during the four hours?
2. What happens to the glowing splint when plunged into the test tube?
3. What is the identity of the gas?
4. What conclusion can you make from this activity?

3.3. Contributions of photosynthesis for the continuity of life, for O_2 and CO_2 balance and global warming

The oxygen in the air comes from photosynthesis. Plants continue to replenish oxygen in the air. All of our food comes directly or indirectly from photosynthesis. Human beings are also dependent on ancient products of photosynthesis (fossil fuels, natural gas, coal & petroleum);

needed for modern industrial energy; complex mix of hydrocarbons; represent remains of organisms that relied on photosynthesis millions of years ago; carbon, oxygen, and hydrogen atoms are recycled in the environment where a constant input of solar energy is needed for energy to continue flowing to support life remove carbon dioxide from the atmosphere (inhibit global warming) (Figure 3.11).

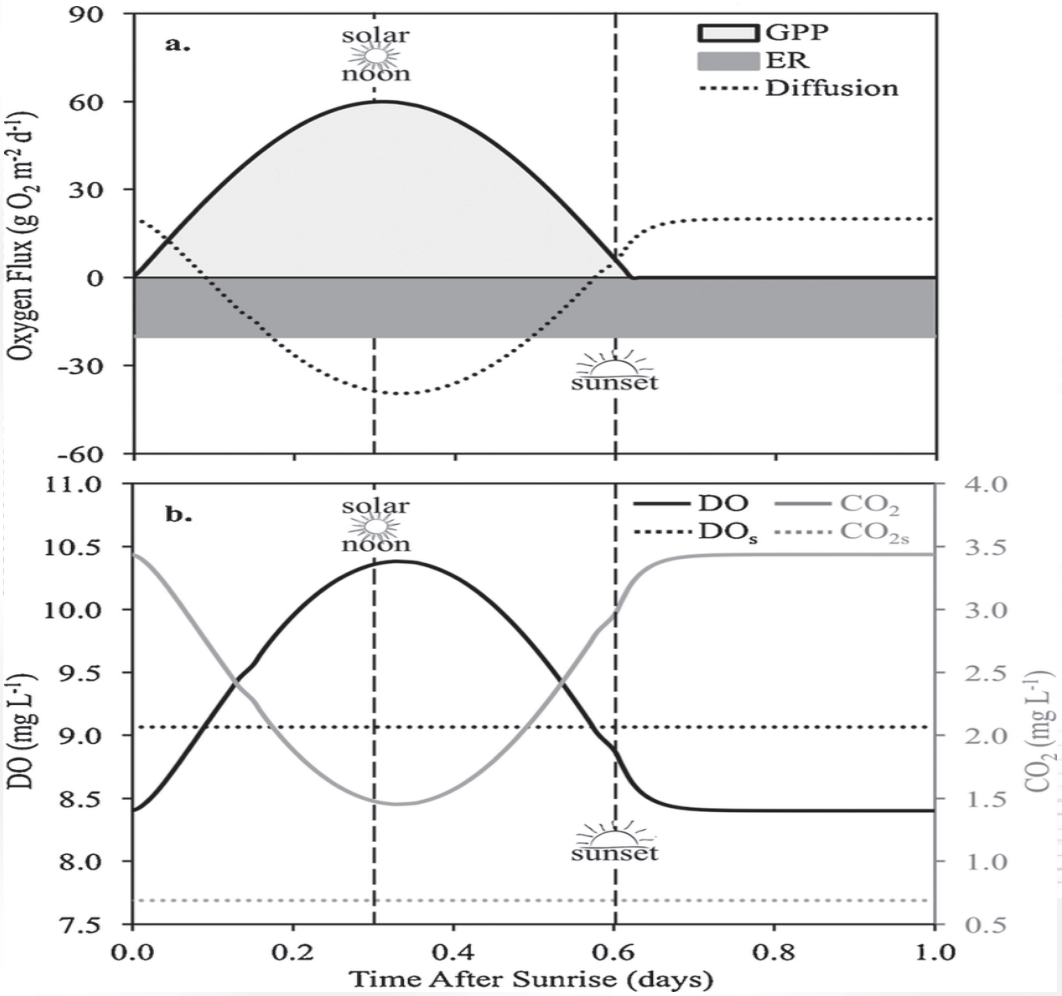


Figure 3.11. Carbondioxide –oxygen balance in the atomospher (Idealized daily rates of photosynthesis (GPP), respiration (ER), and diffusion (a.) with resultant dissolved O 2 concentration and saturated (DO s) concentration at 20 °C (b.)).

Review questions

I. Choose the correct answer for the following questions.

1. Where does the energy come from to drive photosynthesis?

A. Chloroplast C. Sun

B. ATP D. Glucose

4. Only high-energy light can penetrate the ocean and reach photosynthetic organisms in coral reefs. What color light would you predict these organisms use?

a. Red c. Blue b. Yellow d. Orange

5. Which molecules are used to connect the light reactions and the carbon reactions?

a. ATP and ADP c. Glucose b. NADPH and NADP d. Both a and b are correct.

6. A plant that only opens its stomata at night is a

a. C2 plant. c. C4 plant. b. C3 plant. d. CAM plant.

7. Choose the pair of terms that correctly completes this sentence: Catabolism is to anabolism as _____ is to _____.

a. exergonic; spontaneous b. exergonic; endergonic c. free energy; entropy

d. work; energy

8. Most cells cannot harness heat to perform work because

a. heat does not involve a transfer of energy.

b. cells do not have much thermal energy; they are relatively cool.

c. temperature is usually uniform throughout a cell.

d. heat can never be used to do work.

9. Which of the following metabolic processes can occur without a net influx of energy from some other process?

a. $ADP + {\sim}Pi \rightarrow ATP + H_2O$ b. $C_6H_{12}O_6 + 6\ O_2 \rightarrow 6\ CO_2 + 6\ H_2O$

c. $6\ CO_2 + 6\ H_2O \rightarrow 6H_{12}O_6 + 6\ O_2$ d. Amino acids → Protein

10. If an enzyme in solution is saturated with substrate, the most effective way to obtain a faster yield of products is to,

a. add more of the enzyme b. heat the solution to 90°C c. add more substrate d. add a noncompetitive inhibitor.

11. Some bacteria are metabolically active in hot springs because

a. they are able to maintain a lower internal temperature.

b. high temperatures make catalysis unnecessary.

c. their enzymes have high optimal temperatures.

d. their enzymes are completely insensitive to temperature.

3.4. Cellular Respiration

At the end of this lesson, the student will be able to:

- define cellular respiration
- describe the process of glycolysis.
- list the products formed at the end of glycolysis.
- describe the structure of mitochondria.
- explain how energy is harvested in aerobic respiration.
- describe the different stages of aerobic respiration.
- compare and contrast aerobic and anaerobic respiration.
- write the chemical equation of aerobic respiration.
- state the products of alcoholic fermentation by yeast.
- show the mechanism electron transport system in mitochondria.
- explain the difference between substrate-level phosphorylation and

Cellular respiration

It is the process by which cells produce energy from glucose in the form of energy storing compound called ATP(AdenosineTri-Phosphate) for various cellular activities. The energy released by cellular respiration is temporarily captured by the formation of Adenosine Triphosphate (ATP) within the cell. It is often referred to as the energy currency of the cell, and this can be compared to depositing cash in a bank. ATP can be used to store energy for future reactions or be withdrawn to pay for reactions when energy is required by the cell. Animals store the energy obtained from the breakdown of food as ATP. Likewise, plants capture and store the energy they derive from light during photosynthesis in ATP molecules. ATP is a nucleotide consisting of an adenine base attached to a ribose sugar, which is attached to three phosphate groups (**see Figure 3.12**). These three phosphate groups are linked to one another by two high-energy bonds called phosphoanhydride bonds. When one phosphate group is removed by breaking a phosphoanhydride bond in a process called hydrolysis, energy is released, and ATP is converted to adenosine diphosphate (ADP). Similarly, energy is also released when a phosphate is removed from ADP to form adenosine monophosphate (AMP). This free energy can be transferred to other molecules to make unfavorable reactions in a cell favorable.

AMP can then be recycled into ADP or ATP by forming new phosphoanhydride bonds to store energy once again. In the cell, AMP, ADP, and ATP are constantly interconverted as they involve in biological reactions.

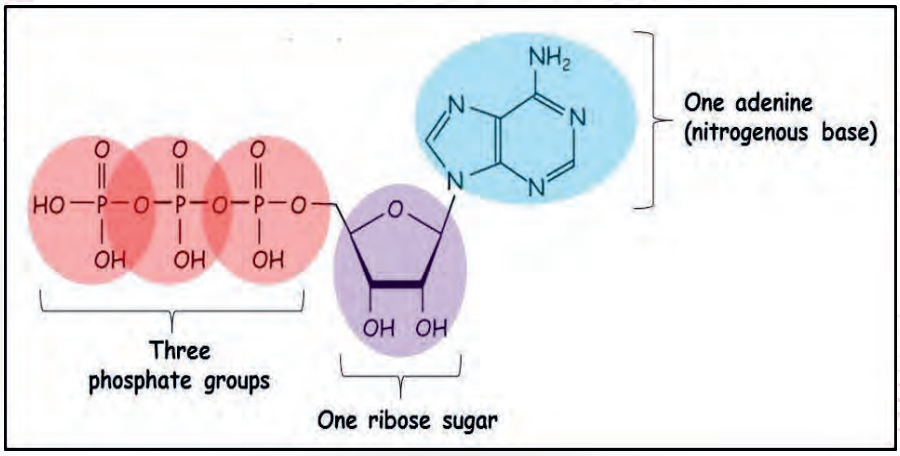


Figure 3.12. Adenosine triphosphate

Coupled Reactions

Many biochemical reactions in which energy is given off- (is called **exothermic**), whereas many others reactions that require energy (are called **endothermic**). In order for both processes

to be carried out efficiently, they must be "coupled". Usually, a **coupled reaction** will involve ATP (Figure 3.13) or some similar molecules. A coupled reaction is carried out when two reactions occur nearly simultaneously. The first reaction must be exothermic and that gives off energy. The second reaction is endothermic, which immediately uses the energy produced from the first reaction.

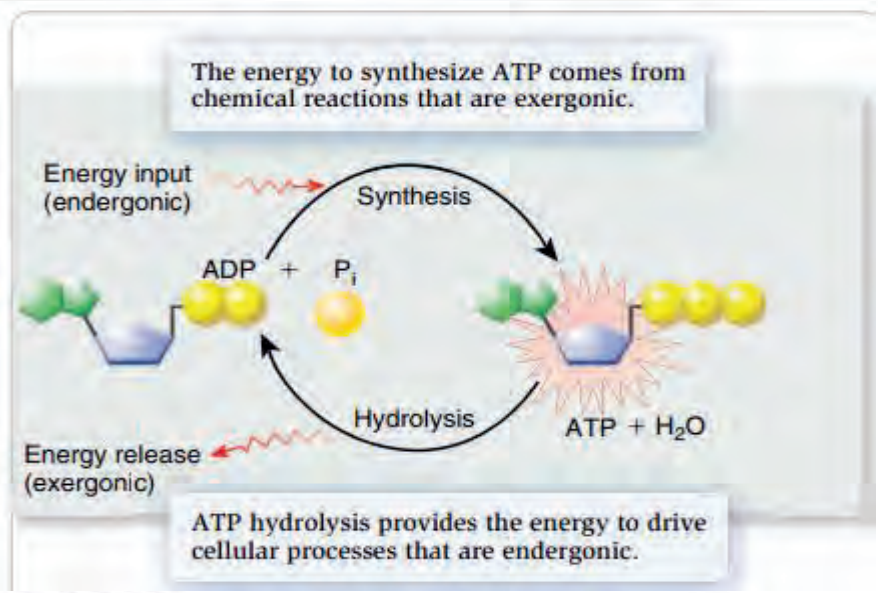


Figure 3.13. ATP cycle

An example of a coupled reaction is the hydrolysis of ATP and the contraction of muscle tissue. Two proteins, actin and myosin, form a loose complex called actomyosin. When ATP is added to isolated actomyosin, the protein fibers contract. The hydrolysis of ATP releases energy which is used by muscles to contract. The coupled reaction is:

A. $ATP + H_2O \rightarrow\rightarrow ADP + P + energy$

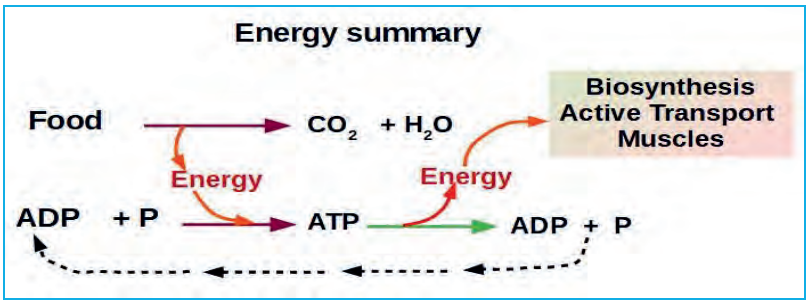
B. Relaxed muscle + energy $\rightarrow\rightarrow$ contracted muscle

When the ATP is used up by the muscles, a further supply of energy is released from creatine phosphate. Another example of a coupled reaction is the hydrolysis of creatine phosphate to release energy which in turn is used for the formation of more ATP. The coupled reaction is:

A. Creatine --- $PO_3 + H_2O \rightarrow\rightarrow$ creatine H + HPO_4^{-3} + energy

B. $ADP + HPO_4^{-3} + energy \rightarrow\rightarrow ATP + H_2O$

During periods of low muscular activity, the reactions are reversed to replenish the supplies of ATP and creatine phosphate. The energy for the formation of ATP is supplied by other metabolic reactions.



3.4.1. The site of cellular respiration

Glycolysis occurs in the cytosol of the cell and does not require oxygen, whereas the Krebs cycle and electron transport occur in the mitochondria and requires oxygen. **Cellular respiration** is carried out by both prokaryotic and eukaryotic cells. In prokaryotic cells, it is carried out in the **cell cytoplasm**, whereas in eukaryotic cells it begins in the **cytosol** then is carried out in the **mitochondria**. In eukaryotes, the four stages of cellular respiration include glycolysis, transition reaction (pyruvate oxidation), the Krebs cycle (also known as the citric acid cycle), and oxidative phosphorylation through the electron transport chain.

Self-questioning

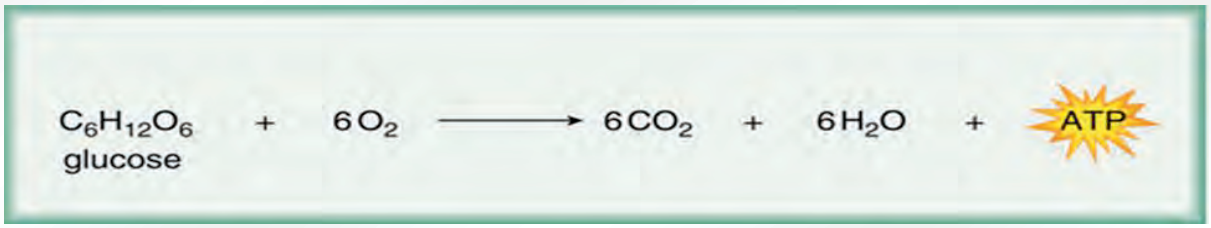
- Why is cellular respiration important?
- What is metabolism on a cellular level?
- Which reactions require energy input and which release energy?
- Why oxidation and reduction reactions always are linked?

3.4.2. Stages of respiration

Cellular respiration involves many chemical reactions. The reactions can be summed up in this equation

Self-questioning

- Where does cellular respiration take place?



Cellular respiration consists of a sequence of many chemical reactions that vary during aerobic and anaerobic conditions. Aerobic respiration is divided into main stages: Glycolysis, Citric acid cycle, and Electron transport chain (Figure 3.14).

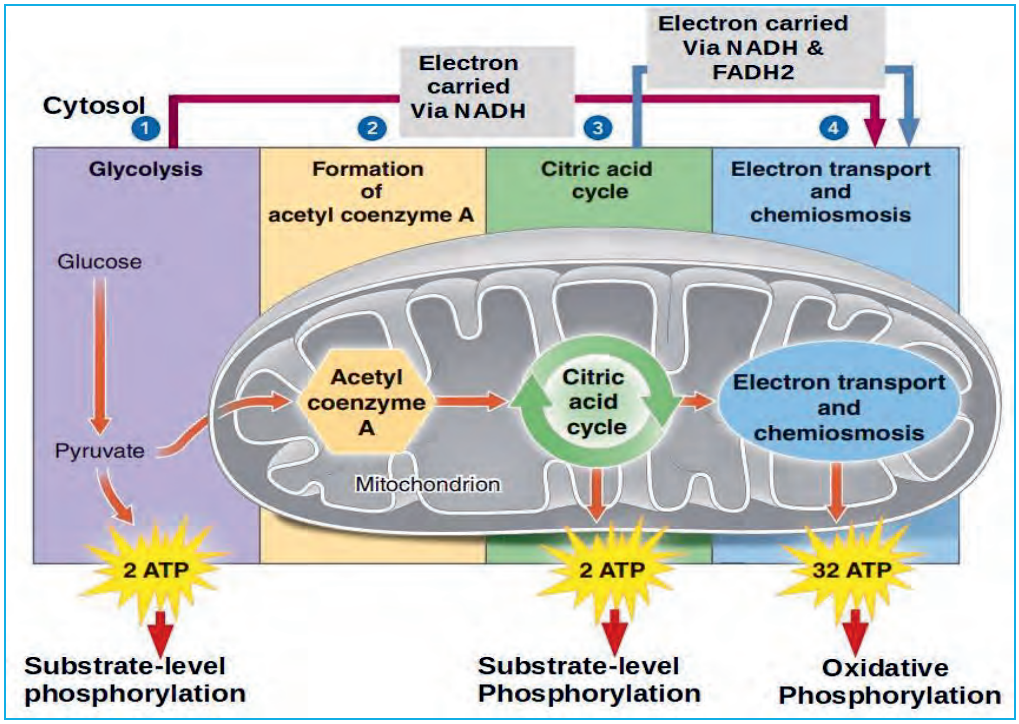


Figure 3.14. Stages of cellular respiration

Stage I: Glycolysis

Glycolysis occurs in the cytosol of the cell in anaerobic condition. It is the common pathway of both aerobic and anaerobic respiration. Glycolysis begins cellular respiration by breaking glucose into two molecules of a three-carbon compound called pyruvate (**Figure 3.14**).


Activity: 3.6. Group work

- Identify the reduced and oxidized compounds from the following equation?

$$C_4H_6O_5 + NAD^+ \rightleftharpoons C_4H_4O_5 + NADH + H^+$$

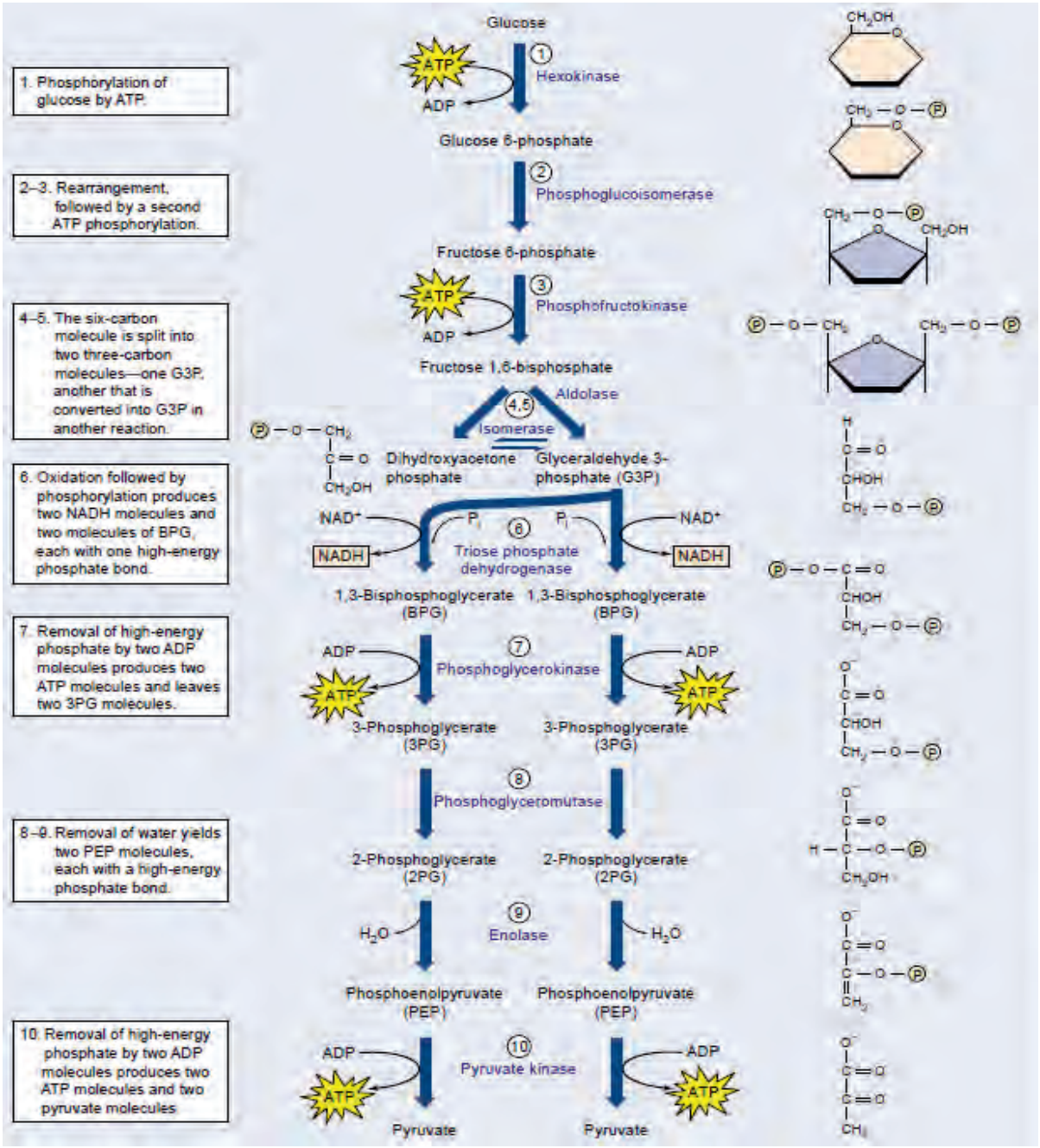


Figure 3.15. Glycolysis pathway.

The 10 steps of glycolysis can be grouped into three phases:

The first phase (steps 1–3) involves an energy investment. Two ATP molecules are hydrolyzed, and the phosphates from those ATP molecules are attached to glucose, which is converted to fructose-1,6-bisphosphate(Figure 3.15). The energy investment phase raises the free energy of glucose, thereby allowing later reactions to be exergonic.

• The cleavage phase (steps 4–5) breaks this six-carbon molecule into two molecules of glyceraldehyde-3-phosphate.

• The energy liberation phase (steps 6–10) produces four ATP, two NADH, and two molecules of pyruvate. Because two molecules of ATP are used in the energy investment phase, the net yield is two molecules of ATP.

Net reaction of glycolysis

$$Glucose + 2ADP + 2NAD^{+} + 2Pi \rightarrow 2Pyruvate + 2ATP + 2NADH + 2H^{+} + 2H_2O$$

Stsge II: Pyruvate oxidation (link reaction)

In order to oxidize to pyruvate, which is the product of glycolysis and enter the next pathway, it must undergo several changes to become acetyl Coenzyme A (acetyl CoA). Acetyl CoA is a molecule that is further converted to oxaloacetate, which enters the citric acid cycle (Krebs cycle). The conversion of pyruvate to acetyl CoA is a three-step process (**Figure 3.16**). Step 1. A carboxyl group is removed from pyruvate, releasing a molecule of carbon dioxide into the surrounding medium. (Note: carbon dioxide is one carbon attached to two oxygen atoms and is one of the major end products of cellular respiration).

Step 2. The hydroxyethyl group is oxidized to an acetyl group, and the electrons are picked up by NAD+, forming NADH (the reduced form of NAD^{+}). The high- energy electrons from NADH will be used later by the cell to generate ATP for energy.

Step 3. The enzyme-bound acetyl group is transferred to CoA, producing a molecule of acetyl CoA. This molecule of acetyl CoA is then further converted to be used in the next pathway of metabolism, or the citric acid cycle.

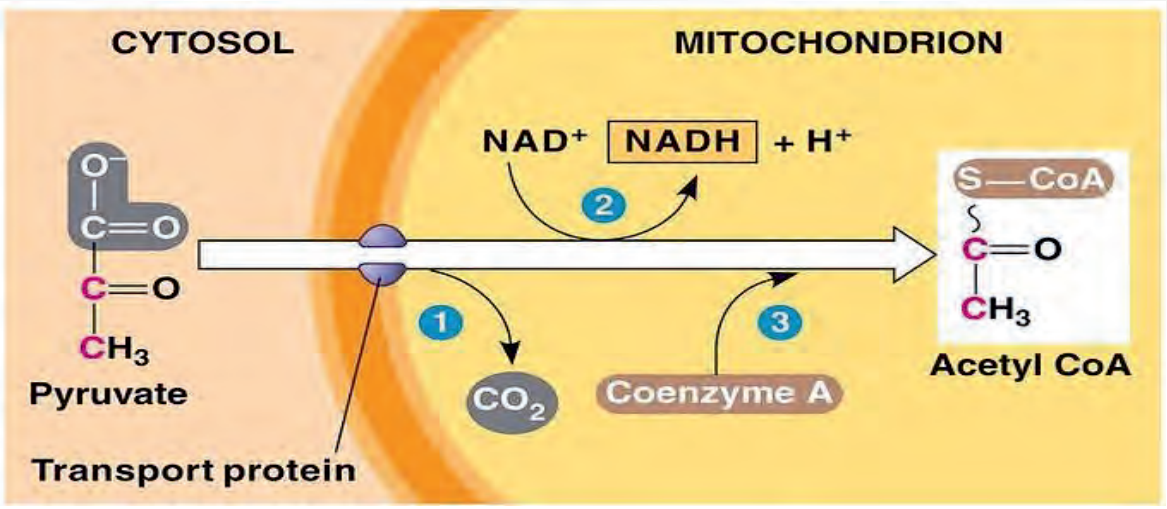


Figure 3.16. Pyruvate oxidation (link reaction)

The overall reaction:

2pyruvate + 2NAD+ + 2 CoA --> 2 acetyl-CoA + 2NADH + 2H+ + 2CO2.

The Acetyl-coA molecules enter the Kreb cycle, NADH goes to the electron transport chain to produce ATP. Carbon dioxide diffuses out of the cell as a waste product. The protons (2H+) stay in the matrix.

Net reaction:

$3NAD+ + FAD + GDP + Pi + acetyl\text{-}CoA + 2\ H_2O \rightarrow 3NADH + FADH_2 + GTP + 2CO_2 + 4H^+$

Stage III: Kreb cycle

The Krebs cycle itself actually begins when acetyl-CoA combines with a four-carbon molecule called OAA (oxaloacetate) (Figure 3.17). This produces citric acid, which has six carbon atoms. This is why the Krebs cycle is also called the citric acid cycle. After citric acid forms, it goes through a series of reactions that release energy. The energy is captured in molecules of NADH, ATP, and FADH2, another energy-carrying compound. Carbon dioxide is also released as product of these reactions. The final step of the Krebs cycle regenerates OAA, the molecule that began the Krebs cycle. This molecule is needed for the next turn through the cycle. Two turns are needed because glycolysis produces two pyruvate molecules when it splits glucose.

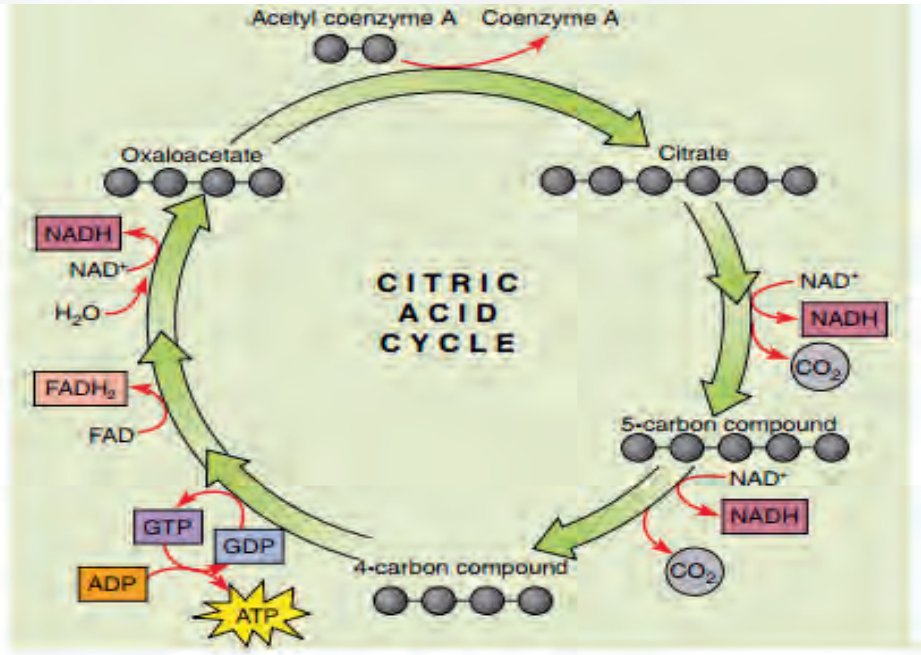


Figure 3.17 citric acid cycle (Krebs cycle)

Activity 3.7. Group work

Discuss in your groups and prepare a presentation on:

- In the citric acid cycle shown in **Figure 3.17**, what molecules capture energy from the redox reactions? How is ATP produced?
- What processes in your cells produce the CO_2 that you exhale?

Stage IV: Oxidative phosphorylation

It is the process in which ATP is formed as a result of the transfer of electrons from NADH or $FADH_2$ to O_2 by a series of electron carriers. This process, which takes place in mitochondria, is the major source of ATP in aerobic organisms. Oxidative phosphorylation generates 26 out of the 30 molecules of ATP that are formed when glucose is completely oxidized to CO_2 and H_2O. The three major steps in oxidative phosphorylation are:

(a) oxidation-reduction reactions involving electron transfers between specialized proteins embedded in the inner mitochondrial membrane;

(b) the generation of a proton (H+) gradient across the inner mitochondrial membrane (which occurs simultaneously with step (a)); and

(c) the synthesis of ATP using energy from the spontaneous diffusion of electrons down the proton gradient generated in step (b) (**Figure 3.18**).

The NADH and $FADH_2$, formed during glycolysis, the link reaction, and the TCA cycle, give up their electrons to reduce molecular O_2 to H_2O. Electron transfer occurs through a series of protein electron carriers, the final acceptor being O_2 and the pathway is called the electron transport chain (ETC). The function of ETC is to facilitate the controlled release of free energy that was stored in reduced cofactors during catabolism. Energy is released when electrons are transported from higher energy NADH/$FADH_2$ to lower energy O_2. This energy is used to phsophorylate ADP. There are 3 sites of the chain that can give enough energy for ATP synthase. These sites are:

Site I between FMN and Coenzyme Q at enzyme complex I.

Site II between cyt b and cyt C1 at enzyme complex III

Site III between cyt a and cyt a3 at enzyme complex IV

Because energy generated by the transfer of electrons through the electron transport chain to O_2 is used in the production of ATP, the overall process is known as oxidative phosphorylation. This oxidation process refers to the coupling of the electron transport in respiratory chain with phosphorylation of ADP to form ATP. It is a process by which the energy of biological oxidation is ultimately converted to the chemical energy of ATP. Oxidative phosphorylation is responsible for 90% of the total ATP synthesis in the cell. Oxidative phosphorylation is the process in which ATP is formed as a result of the transfer of electrons from NADH or $FADH_2$ to O_2 by a series of electron carriers (Figure 3.17).

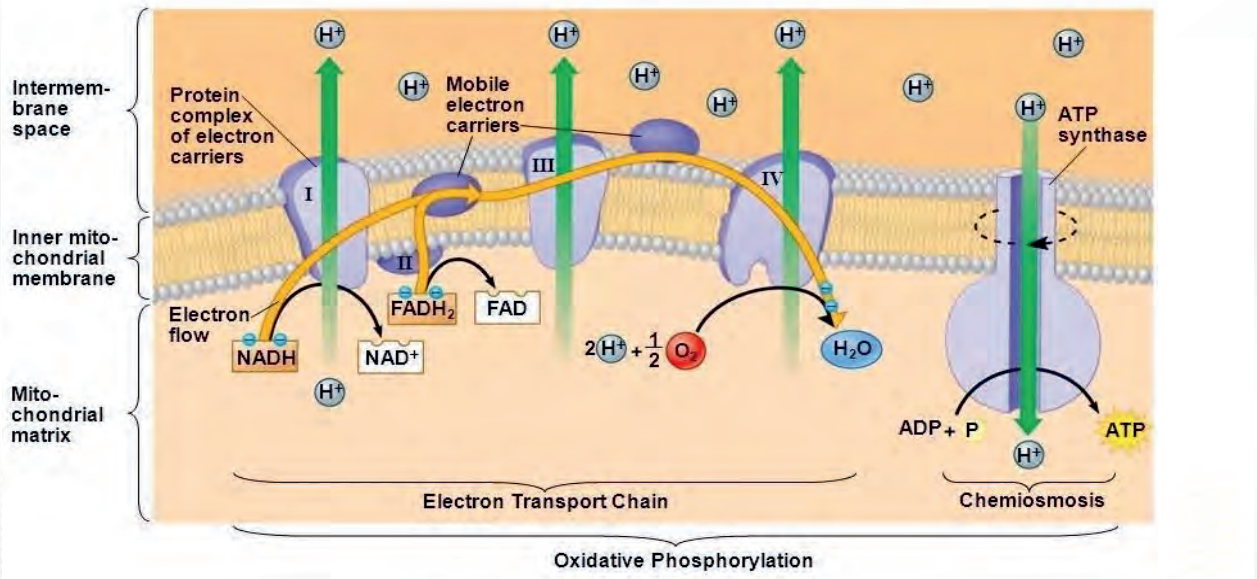
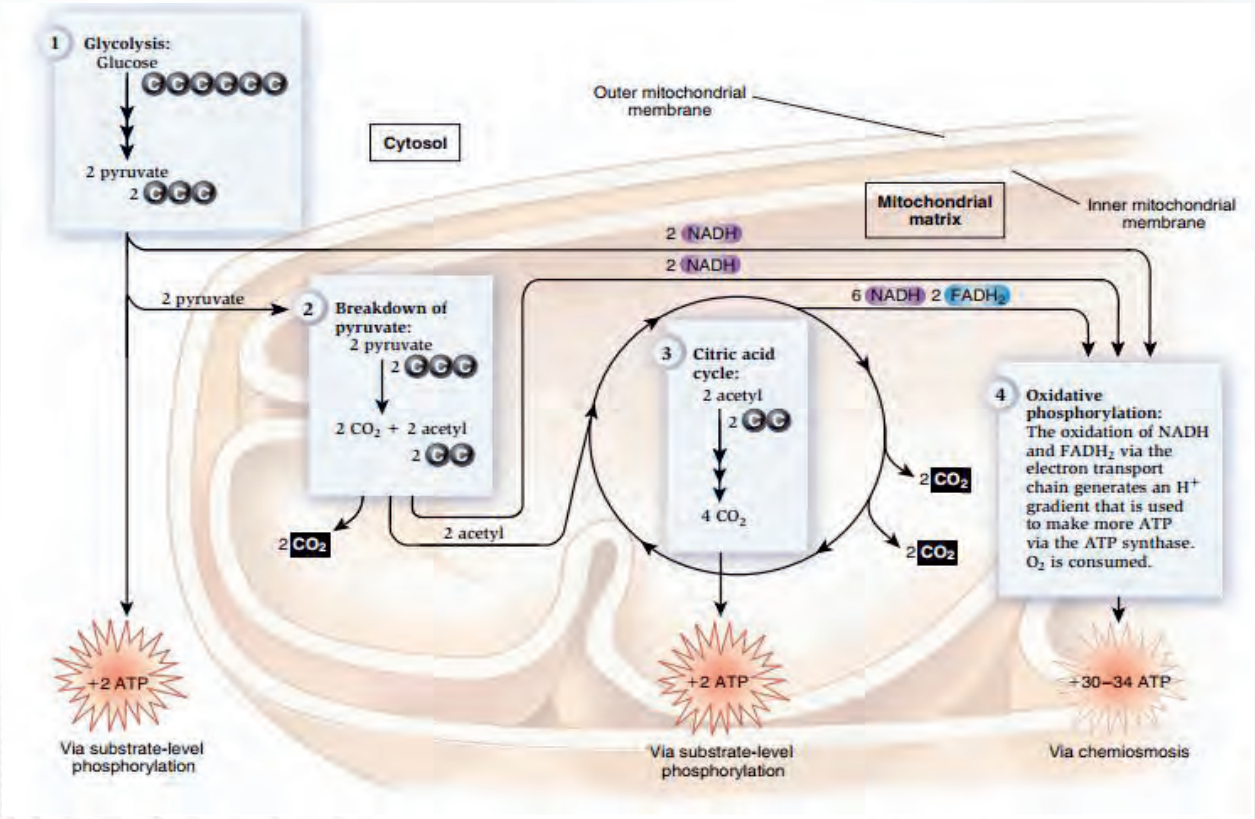


Figure 3.18. Electron transport and oxidative phosphorylation

S



Mechanism

Mechanism suggests that the transfer of electrons through the electron transport chain causes protons to be translocated (pumped out) from the mitochondrial matrix to the intermembrane space at the three sites of ATP production (i.e. it acts as a proton pump) resulting in an electrochemical potential difference across the inner mitochondrial membrane.

The electrical potential difference is due to the accumulation of the positively charged hydrogen ions outside the membrane, whereas the chemical potential difference is due to the difference in pH when it is more acidic outside the membrane. This electrochemical potential difference drives (forces) ATP synthase to generate ATP from ADP and inorganic phosphate.

(Figure 3.19).

The energy budget of one glucose molecule

As from one glucose molecule, two pyruvate molecules are formed so that two cycles will be formed for the complete breakdown. So, the total yield will be 6NADH, 2FADH2, and 2 ATP

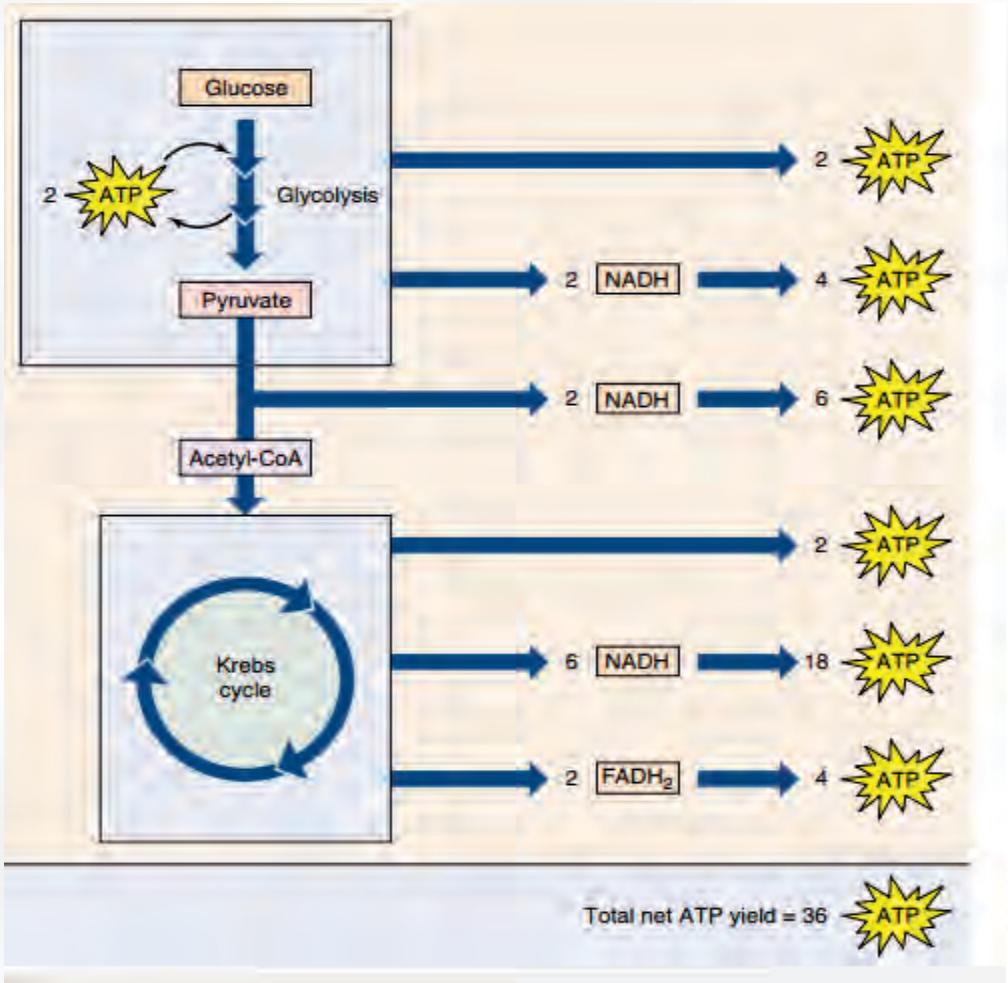


Figure 3. 19. Energy yield per glucose molecule breakdown.

Self-questioning

What couples the electron transport chain to ATP synthesis?

Energy from non-carbohydrate sources

We obtain most of our energy in the form of fats, proteins, sucrose and other disaccharides, and starch, a polysaccharide. All these organic molecules in food can be used by cellular respiration to make ATP **(Figure 3.20)**.

Glycolysis can accept a wide range of carbohydrates for catabolism. In the digestive tract, starch is hydrolyzed to glucose, which can then be broken down in the cells by glycolysis and the citric acid cycle. Similarly, glycogen, the polysaccharide that humans and many other animals store in their liver and muscle cells, can be hydrolyzed to glucose between meals as fuel for respiration. The digestion of disaccharides, including sucrose, provides glucose and other monosaccharides as fuel for respiration.

Proteins can also be used for fuel, but first they must be digested to their constituent amino acids. Many of the amino acids are used by the organism to build new proteins. Amino acids present in excess are converted by enzymes to intermediates of glycolysis and the citric acid cycle. Before amino acids can feed into glycolysis or the citric acid cycle, their amino groups must be removed, a process called *deamination*. The nitrogenous refuse is excreted from the animal in the form of ammonia (NH3), urea, or other waste products.

Catabolism can also harvest energy stored in fats obtained either from food or from storage cells in the body. After fats are digested to glycerol and fatty acids, the glycerol is converted to glyceraldehyde 3-phosphate, an intermediate of glycolysis. Most of the energy of a fat is stored in the fatty acids. A metabolic sequence called **beta oxidation** breaks the fatty acids down to two-carbon fragments, which enter the citric acid cycle as acetyl CoA.

NADH and FADH2 are also generated during beta oxidation; they can enter the electron transport chain, leading to further ATP production. Fats make excellent fuels, in large part due to their chemical structure and the high energy level of their electrons (equally shared between carbon and hydrogen) compared to those of carbohydrates. A gram of fat oxidized by respiration produces more than twice as much ATP as a gram of carbohydrate. Unfortunately, this also means that a person trying to lose weight must work hard to use up fat stored in the body because so many kilojoules are stockpiled in each gram of fat.

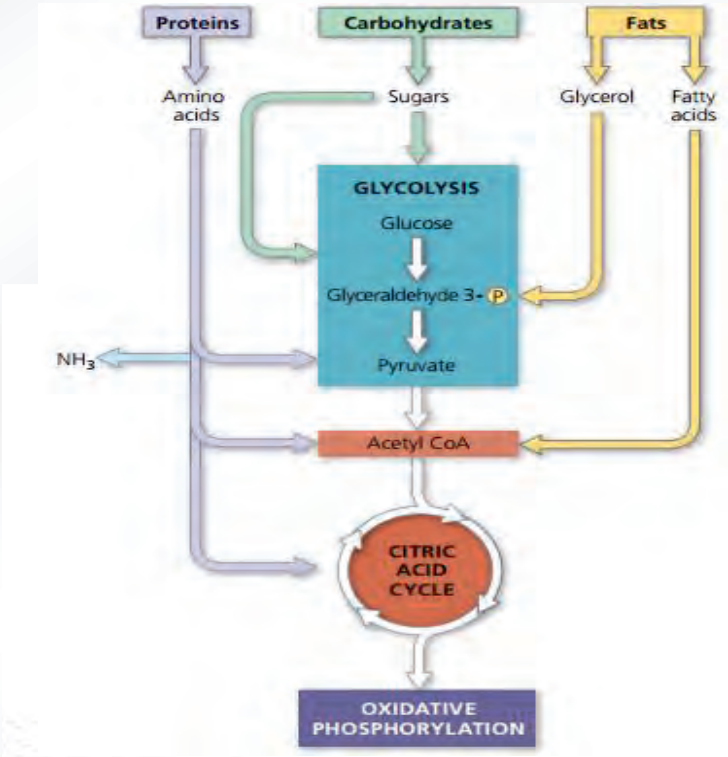


Figure 3. 20. The cataboism of various molecules from food.

Activity 3.8. Group work

Discuss in your groups and prepare a presentation on:

- What effect would an absence of O_2 have on the process shown in Figure 2.29?
- In the absence of O_2, as in question 1, what do you think would happen if you decreased the pH of the intermembrane space of the mitochondrion? Explain your answer.
- Membranes must be fluid to function properly. How does the operation of the electron transport chain support that assertion?

Two ideas to keep in mind

1. The idea of net gain of ATP is like the profit a business person makes. It invests in money materials, advertising and building the capacity of staff. He/ She sell his/her product where the extra money is profit – net gain. In a similar vein, glycolysis 'invests' in two molecules of ATP to make the glucose reactive, then, later, produces **four molecules of ATP** – a net gain of two molecules of ATP.

2. There are two molecules of pyruvate made from each molecule of glucose. So, all the gains of ATP and the reduced NAD and reduced FAD that accrue from each pyruvate must be doubled to give the gain from each molecule of glucose.

Key words

Coenzyme A coenzyme is derivedfrom a pantothenic acid needed for respiration

Acetyl coenzyme A is producedby the reaction of coenzyme Awith a molecule of pyruvate

Dehydrogenation refers to the process of removinghydrogen from a molecule

Decarboxylation means removing carbon from a molecule

Terminal electron acceptor is the final molecule at the end of the electron transport chain to accept an electron

Activity 3.9 group work

Make a large annotated wall chart **showing** glycolysis and Krebs cycle and how they are linked together. Make sure that you show the different compounds and where ATP is formed. This should be as accurate as possible so that it can form the basis of your revision of this complex topic.

The summary equation for aerobic respiration is:

$C_6H_{12}O_6 + 6O_2 \rightarrow 6H_2O + 6CO_2$ + energy released

Fermentation

What happens in the anaerobic pathway?

In the process of glycolysis, a net profit of two ATP was produced, two NAD+ were reduced to two NADH + H+, and glucose was split into two pyruvate molecules. When oxygen is not present, pyruvate will undergo a process called fermentation. In the process of fermentation, the NADH + H+ from glycolysis will be recycled back to NAD+ so that glycolysis can continue. In the process of glycolysis, NAD+ is reduced to form NADH + H+. If NAD+ is not present, glycolysis will not be able to continue. During aerobic respiration, the NADH formed in the glycolysis will be oxidized to reform NAD+ for use in glycolysis again. When oxygen is not present or if an organism is not able to undergo aerobic respiration, pyruvate will undergo a process called fermentation. Fermentation does not require oxygen and is therefore anaerobic.

Self-questioning

- How do respirometers work?
- What are respirometers used for?
- How does a respirometer measure oxygen uptake?
- How do you use a respirometer a level biology?

Fermentation will replenish NAD+ from the NADH + H+ produced in glycolysis.

One type of fermentation is alcohol fermentation. First, pyruvate is decarboxylated (CO_2 leaves) to form acetaldehyde. Hydrogen atoms from NADH + H+ are then used to help convert acetaldehyde to ethanol where NAD+ results. Facultative anaerobes are organisms that can undergo fermentation when they are deprived of oxygen. Yeast is an example of a

facultative anaerobe that will undergo alcohol fermentation (Figure 3.22).

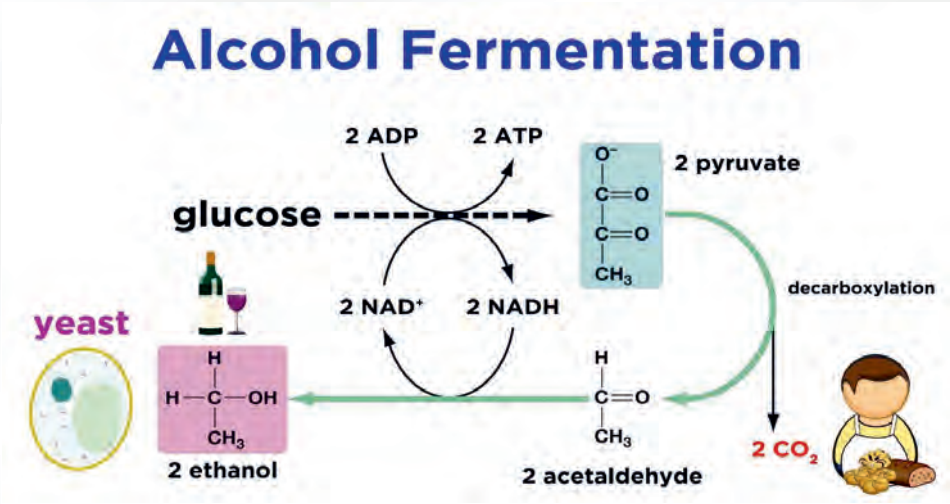


Figure 3.22. Alcohol fermentation

Lactic acid fermentation

Lactic Acid Fermentation: is the process by which pyruvate molecules are converted to lactic acid in the muscle cells of humans, and also in the cells of bacteria.

During lactic acid fermentation, the pyruvate molecules from glycolysis are used to oxidize NADH and convert it back to NAD^+. During the process, lactic acid or lactate is produced as a byproduct. Most animals and some bacteria can carry out lactic acid fermentation. Animals use the process to regenerate NAD+ in the absence of oxygen (Figure 3.23). Anaerobic respiration doesn't produce enough ATP to power the entire organism, but can be used to supplement the ATP levels in tissues (like muscle) where oxygen levels may drop quickly. The products of bacterial lactic acid fermentation have been used by humans to produce food products such as yogurt, sour cream, and buttermilk.

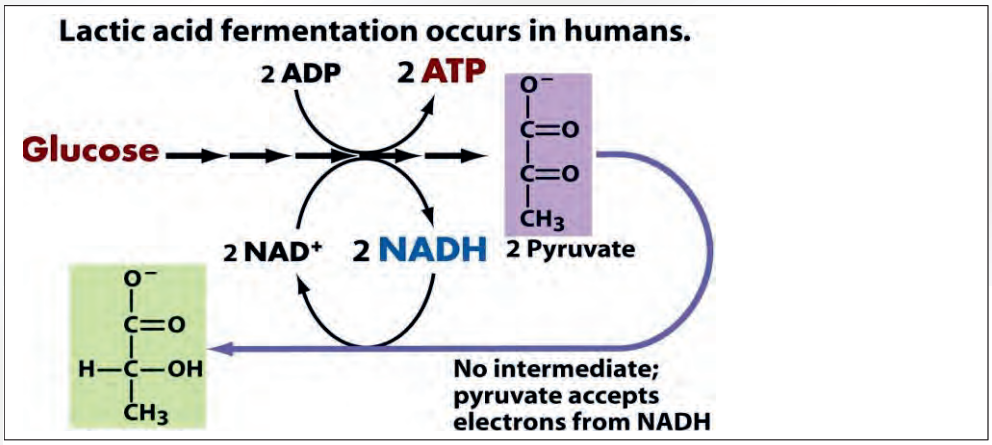


Figure 3.23. Lactic acid fermentation

Activity 3.10. Investigation of the rate of fermentation in yeast

There are many different ways of carrying out this investigation, that range from those using only basic equipment to sophisticated electronically monitored fermenters.

The test tube containing the yeast and glucose can be held in a water bath at the desired temperature and the number of bubbles collected per minute recorded. However, rate of bubbling is not the most accurate way of measuring rate of respiration. Are you sure that all the bubbles are the same volume? The method is improved if the gas syringe replaces test tube of water.

Using this basic equipment, devise experiments to investigate:

- the effect of temperature on the rate of fermentation the effect of different substrates (different sugars) on the rate of fermentation
- the effect of substrate concentration on the rate of fermentation

In your plans, you should make clear:

- The independent variable
- The dependent variable
- Other variables that you intend to control as well as:
  - Why you need to control them, and
  - How you intend to control them.
- More sophisticated fermenters control all the conditions inside the fermenter and monitor the changes in the concentration of oxygen, carbon dioxide and ethanol. Other sensors could also monitor the concentration of the sugar being fermented.
  - Can you explain the changes in the concentrations of the various substances as fermentation proceeds?

Table 1. Results from Part A.

Tube #	Sugar	Start Time	End Time	Duration (Min)	Volume of CO_2 (ml)	Fermentation rate(ml CO2/min)
1	Glucose					
2	Fructose					
3	Sucrose					
4	Lactose					

Introduction for Part B – Effect of Temperature on Fermentation

In this experiment you will be investigating the effects of temperature on the fermentation rate of yeast. As in Part A, CO2 production will be used as a measure of fermentation rate. However, instead of manipulating the sugar types, only one sugar (glucose) will be used in all the fermentation tubes. The fermentation tubes will be placed in water baths of different temperatures (0°C, ~22°C, 37°C, and 70°C) to see how the temperatures affect the fermentation rates.

Procedure for Part B:

1. Label 4 clean fermentation tubes (1- 4). Using the graduated cylinder in your tray, measure and pour 5 ml of the yeast suspension into each of your four fermentation tubes. Be sure to mix the suspension before dispensing. You may need to use a pipette to accurately bring the volume of the graduated cylinder to exactly 5 ml.

2. using the graduated cylinder, add 7 ml of glucose solution to each of the fermentation tubes.

3. Tip the fermentation tubes so that the vertical column of each tube fills with the liquid.

4. Place tube #1 in the 0° C ice-water bath; tube #2 in the room temperature bath (record the exact temperature in Table 2); tube #3 in the 37° C water bath; and tube #4 in the 70° C water bath. Record the time in Table 2.

5. Monitor the amount of CO_2 produced. This may take some time. When ONE of the tubes is half filled with CO_2, note the time, and remove ALL tubes from the water bath.

6. Measure the volumes (in ml) of gas in each tube and record them in the table below.

Calculate the fermentation time by subtracting the starting time from the ending time, and record it in the table. Calculate the fermentation rates at each of the temperatures from these data.

7. BEFORE YOU THROW ANYTHING AWAY!!!...Take tubes #1 (0° C) and #4 (70° C) and place them both in the 37° C water bath for 5 minutes to let them both equilibrate to that temperature. After 5 minutes, tip the tubes to mix and remove the air, and leave them in the bath to incubate. Record the time.

8. Monitor the amount of CO2 produced. This may take some time. When ONE of the tubes is half filled with CO2, note the time, and remove BOTH tubes from the water bath.

9. Measure the volume (in ml) of gas in each tube and record them it Table 2 below. Calculate the fermentation time by subtracting the starting time from the ending time, and record it in the table. Calculate the fermentation rate at each of the temperatures from these data.

10. WASH AND RINSE ALL OF YOUR TUBES (contents can be poured down the sink). Tip the tubes as you wash them to thoroughly clean them.

Table 2. Results from Part B.

Tube #	Temp. ^{o}C	Temp. ^{o}F	Start Time	End Time	Duration (min)	Volume of CO_2 (ml)	Fermentation rate (ml CO_2/min)
1	0						
2							
3	37						
4	70						
1	0→37						
4	70→37						

Unit Summary

Metabolism is the sum of chemical reactions that takes place within each cell of an organism. The chemical reactions enable cells to produce energy for vital processes and also synthesize new organic materials. Broadly, these reactions can be divided into catabolic reactions that convert nutrients to energy and anabolic reactions that lead to the synthesis of larger biomolecules.

Photosynthesis is the process by which photosynthetic organisms convert the energy of sunlight into chemical energy stored in sugars. Inside a chloroplast, photosynthesis occurs in two stages: the light-dependent reactions and the light-independent (or Calvin Cycle) reactions.

The light dependent reactions, a light-dependent series of reactions which occur in the grana, and require the direct energy of light to make energy-carrier molecules (NADPH and ATP) that are used in the light independent phase.

The light-independent reactions, a light-independent series of reactions which occur in the stroma of the chloroplasts, when the products of the light reaction, ATP and NADPH, are used to make carbohydrates from carbon dioxide (reduction); initially glyceraldehyde 3-phosphate (a 3-carbon atom molecule) is formed.

Cellular respiration is the process by which cells produce energy from glucose in the form of energy storing compound called ATP(AdenosineTri-Phosphate) for various cellular activities. Cellular respiration can take place in the presence as well as in the absence of oxygen. When it utilizes oxygen, it reffered to as aerobic respiration. Aerobic respiration takes place in the mitochondria. It is more efficient as it yields about 36-38ATP per mole gilucose consumed. During glycolysis, glucose molecules (six-carbon molecules) are split into two pyruvates (three-carbon molecules) during a sequence of enzyme-controlled reactions. Glycolysis takes place in the cytosol or cytoplasm.

Anaerobic respiration occurs in the absence of oxygen. Without oxygen, pyruvate is converted to lactic acid in animals or ethanol in plants and yeast. It produces only about 10% of the energy released in the complete oxidation of glucose.

Anaerobic respiration in humans takes place when muscle undergoes extreme contraction as in vigorous exercise. When oxygen is limited the oxidation of NADH to NAD^+ by the electron transport chain is insufficient to maintain glycolysis. Under these conditions NAD^+ is regenerated by the reduction of pyruvate to lactate.

Unit review questions

I. Choose the correct answer for the following questions.

1. Where does the energy come from to drive photosynthesis?
   A. Chloroplast C. Sun
   B. ATP D. Glucose
2. Which colors light is predominantly absorbed by the chlorophyll?
   A. Red B. Green C. Yellow D. Orange
3. Which plant usually opens its stomata during night time?
   A. C2 plant. B. C3 plant. C. C4 plant. D. CAM plant.
4. Which of the following processes takes place during the dark reaction of photosynthesis?
   A. Photolysis of water C. Production of ATP
   B. Fixation of CO_2 D. Production of NADPH
5. Where do the enzymatic reactions of the Calvin cycle take place?
   A. stroma of the chloroplast. C. cytoplasm of plant cell
   B. thylakoid membranes D. outer membrane of the chloroplast
6. Why are C4 plants able to photosynthesize with no apparent photorespiration?
   A. They are capable of excluding oxygen from their tissues.
   B. They have a mechanism to use PEP carboxylase to initially fix CO_2.
   C. They have special adaptations to cold and wet climatic conditions.
   D. They are capable of conserving water more efficiently.
7. The equation below represents a summary of a biological process.
   Glucose + Oxygen → Carbon dioxide + Water + Energy
   Where does this process take place in the cell?
   A. Cytoplasm C. Thylakoid of chloroplast
   B. Mitochondrial matrix D. Stroma of Chloroplast
8. What is the role of oxygen in cellular respiration?
   A. It is directly invoved in the oxidation of glucose during glycolysis.
   B . It accepts electrons during oxidation of pyruvate to acetyl CoA.
   C. It is directly involved in the oxidation process of the citric acid cycle.
   D. It accepts electrons at the end of the electron transport chain.
9. Which metabolic pathway is common to both cellular respiration and fermentation?
   A. The citric acid cycle

B. The oxidative phosphorylation.

C. The process of glycolysis,

D. The oxidation of pyruvate to acetyl CoA.

10. How does photorespiration reduce the efficiency of photosynthesis?

A. By preventing the formation of carbon dioxide molecules.

B. By preventing the formation 3-phosphoglycerate molecules

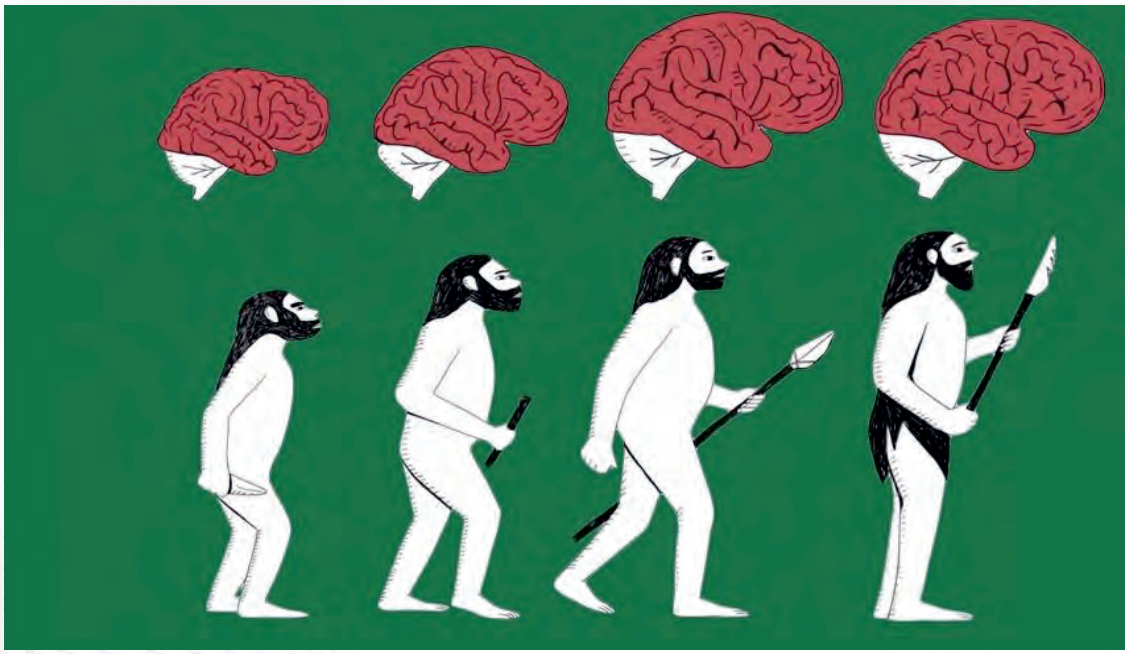
C. By enhancing the formation of oxygen molecules.

D. By enhancing the formation of RuBP carboxylase molecules.

II. Answer the following questions

1. Distinguish between anabolic and metabolic pathways.
2. Describe the process of cellular respiration.
3. Justify why oxidation of glucose involving mitochondrion is more efficient.
4. During a race how can your muscles cells produce ATP if oxygen deficiency occurs?
5. What are the chlorophyll pigments responsible for absorption of light spectra?
6. Compare cyclic and non-cyclic photophosphorylation
7. What are the products of the light reacttions subsequently used by the Calvin cycle?
8. Where do the enzymatic reactions of the Calvin cycle take place?
9. Compare the mechanism of carbon fixation C3 and C4 plants.
10. What is the primary function of the Calvin cycle?
11. Compare the process of photosynthesis and cellular respiration.
12. Justify how the processes of cellular respiration and photosynthesis help to maintain the balance of CO_2 and O_2 in the atmosphere.

UNIT 4: EVOLUTION



4.1. EVOLUTION

After successful completion of this unit, the learner will be able to:

- Analyze different views about the origin of life and evaluate views from a scientific explanations point of view
- Describe scientific evidence to support that modern living things have evolved from a common ancestor.
- Explain the major causes of evolution that lead to variation in organisms
- Appreciate the role of natural selection and survival of the fittest in evolution and day to day life

4.1.1. Definition

 By the end of this section, the learner will be able to:

- Define evolution.
- Debate on the different thoughts of the origin of life.

 Self-Assessment Questions

- What do you understand by the word 'evolution'?
- Have you ever asked yourself how did all millions of new species appear on our planet? Explain

Evolution is a change in genetic composition of a population over successive generations, which may be caused by meiosis, hybridization, natural selection or mutation. This leads to a sequence of events by which the population diverges from other populations of the same species and may lead to the origin of a new species.

 Keyword

Evolution- The theory of evolution describes how the various forms of life on Earth (including humans) emerged and evolved.

Theories of the origin of life

The origin of life means the emergence of heritable and evolvable self-reproduction. "Origin of Life" is a very complex subject, and oftentimes controversial. Two opposing scientific theories that existed on this complex subject for a long time were the so called **intelligent design** and **creationism**. The **big bang theory of the origin of the Universe** gave new ideas about the topic of biological evolution. In the theory it has been hypothesized that complex life-forms on Earth, including humans, arose over a period of time from simple bacteria like tiny cells by a process of self-organization similar to the evolution of the Universe of simple

Keyword

Creationism (or special creationism) is a theory claiming that the different forms of life on Earth were created by a supreme being.

 Self-questioning

What basic differences can you draw from the following regarding the origin of life?

- Religious thoughts and science
- Observation, provable events and empirical facts against opinions about morality or purpose

material structures toward more and more complex structures. There are several theories about the origin of life. Some of them are mentioned below.

1. Special creationism

Special creationism explained that the formation of life on earth may have been taken place due to **supernatural** or **divine forces**. However, acceptance of evolution is linked to scientific thinking. There are fundamental differences between special reationism and scientific thinking in that it is nlikely that the difference between the two will ever be resolved. Special creation states that at some stage, some supreme being created life on Earth. There are many different versions of special creation, linked with different religions. Often, there is considerable variation as to how rigidly the special creation theory is interpreted within a religion.

Activity 4.1

Make a small group and read from different sources about the following forms of creationism theories and reflect your idea to the class.

-Young Earth creationism
- Old Earth creationism
- Day-age and gap creationism
- Progressive creationism
- Theistic evolution/
- Evolutionary creationism
- Intelligent design

2. Spontaneous generation (abiogenesis)

Spontaneous generation suggests that some life can evolve spontaneously' from non-living objects. The Greek philosopher Aristotle (384-322) was one of the earliest scholars to articulate the theory. It was once believed that life could come from nonliving things, such as mice from corn, flies from bovine manure, maggots from rotting meat, and fish from the mud of previously dry lakes.

Keyword

Spontaneous generation- a theory that claimed that some types of organism could come into being almost instantly from non-living materials

In 1668, Francesco Redi, an Italian scientist, designed a scientific experiment to test the spontaneous creation of maggots by placing fresh meat in jars (Figure 4.1). One jar was left open; the others were covered with a cloth. Days later, the open jar contained maggots, whereas the covered jars contained no maggots. He did note that maggots were found on the exterior surface of the cloth that covered the jar. Redi successfully demonstrated that the maggots came from fly eggs and thereby helped to disprove spontaneous generation.

In 1748, the English priest John Needham (1713–1781) reported the results of his experiments on spontaneous generation. Needham boiled mutton broth and then tightly stoppered the flasks. Eventually many of the flasks became cloudy and contained microorganisms. He thought organic matter contained a vital force that could confer the properties of life on nonliving matter.

A few years later, the Italian priest and naturalist Lazzaro Spallanzani (1729–1799) improved on Needham's experimental design by first sealing glass flasks that contained water and seeds. If the sealed flasks were placed in boiling water for 3/4 of an hour, no growth took place as long as the flasks remained sealed. He proposed that air carried germs to the culture medium, but also commented that the external air might be required for growth of animals already in the medium. The supporters of spontaneous generation maintained that heating the air in sealed flasks destroyed its ability to support life.

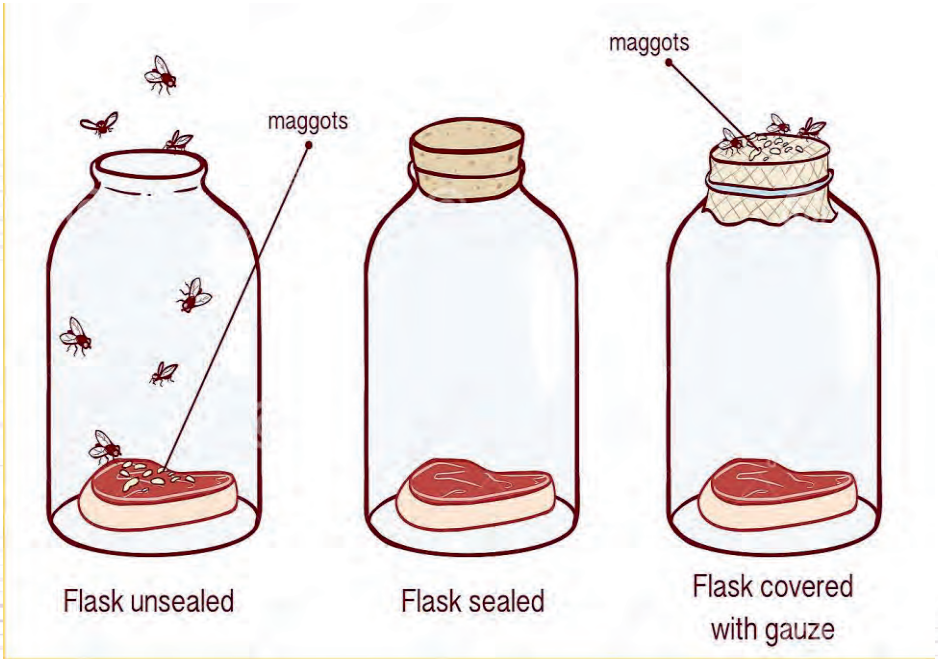


Figure 4.1 Fransesco Redi's experiment set up.

Louis Pasteur, the notable French scientist, showed that broth (or wine) only went sour if micro-organisms were allowed to enter. Also no micro-organisms appeared in the broth unless they were allowed to enter from the outside (Figure 4.2). Pasteur made a series of flasks with long, twisted necks ("swan-neck" flasks), in which he boiled broth to sterilize it (Figure 4.2). His design allowed air inside the flasks to be exchanged with air from the

outside, but prevented the introduction of any airborne microorganisms, which would get caught in the twists and bends of the flasks' necks. If a life force besides the airborne microorganisms were responsible for microbial growth within the sterilized flasks, it would have access to the broth, whereas the microorganisms would not. He correctly predicted that sterilized broth in his swan-neck flasks would remain sterile as long as the swan necks remained intact. However, should the necks be broken, microorganisms would be introduced, contaminating the flasks and allowing microbial growth within the broth. Pasteur's set of experiments irrefutably disproved the theory of spontaneous generation and also articulated "Omne vivum ex vivo" ("Life only comes from life")

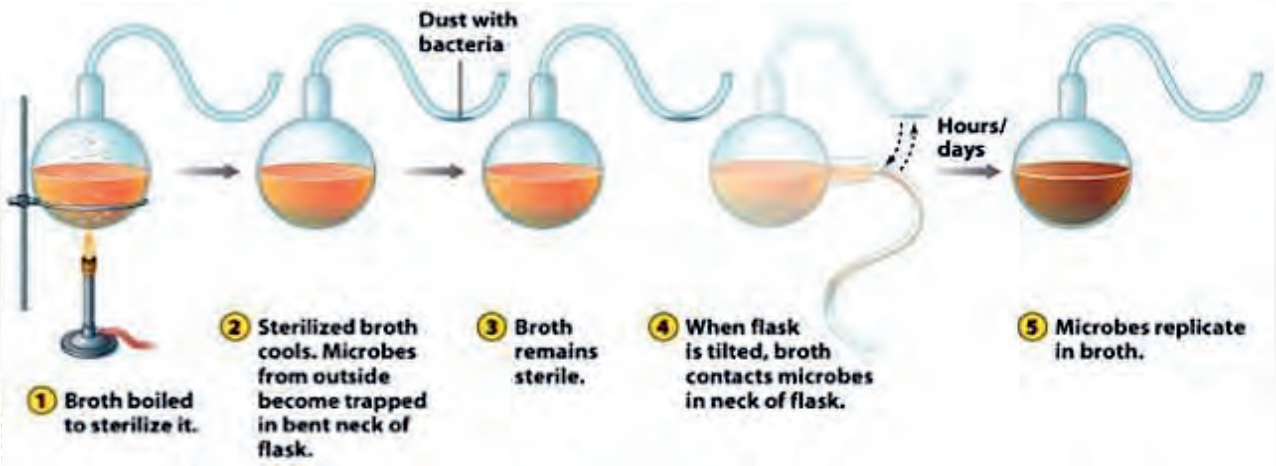


Figure 4.2 Louis Pasteur's experimental set up to disprove spontaneous generation

These two scientists showed that both macro-organisms (Redi) and micro-organisms (Pasteur) could only arise from pre-existing organisms, disproving the theory of spontaneous generation. But what about the first ever cell? Unless we believe that life is eternal, with no beginning and no end, there had to be a first cell. It could not have come from a pre-existing cell because it was the first.

Keyword

Eternity of life theory- claims that the Universe has always existed and that there has always been life in the Universe.

Activity 4.2

Write a report describing carefully how we now know that spontaneous generation is not possible and does not happen.

3. Eternity of life

In this theory of life, there is no beginning and no end to life on Earth and so life neither needs special creation nor does it need to be generated from non-living matter. Supporters of this theory believe that life is an inherent property of the Universe and it has always existed as has the Universe.

At the time when such theories were being propounded, many eminent scientists – including Albert Einstein – believed that the Universe was unchanging. They reasoned that 'if life is found today in an unchanging Universe, then it must always have been there'.

4 Cosmozoan theory, Panspermia or Spore broth theory

Activity 4.3

Make a small group and search for books or other resources (internet) about steady state theory of the Universe? Can eternity of life theory linked to this theory? Report your finding to the class.

According to **Cosmozoan theory** life has reached this planet Earth from other cosmological structures, such as meteorites, in the form of highly resistant spores. This theory was proposed by Richter (1865). According to this theory, 'protoplasm' reached the earth in the form of spores or germs or other simple particles from some unknown part of the universe with the cosmic dust, and subsequently evolved into various forms of life.

Figure 4.3 A meteorite fall to Earth

Keyword

Cosmozoan theory claims that life on Earth originally came from elsewhere in the Universe (possibly from another planet).

Helmholz (1884) speculated that 'protoplasm' in some form reached the earth with falling meteorites.

Activity 4.3

Search from books or other sources about panspermia and pseudo-panspermia theories. How do they explain the origin of life on earth? Try to gather evidence against this theory as living matter cannot survive the extreme cold, dryness and ultra-violet radiation from the sun required to be crossed for reaching the earth. Report your finding to the class.

4. Biochemical origin

The current ideas we have about how life may have evolved on Earth as a result of biochemical reactions (sometimes called abiogenesis) owe much to two biologists working early in the twentieth century.

Keyword

Biochemical theory suggests that life on Earth originated as a result of a number of biochemical reactions producing organic molecules which associated to form cells.

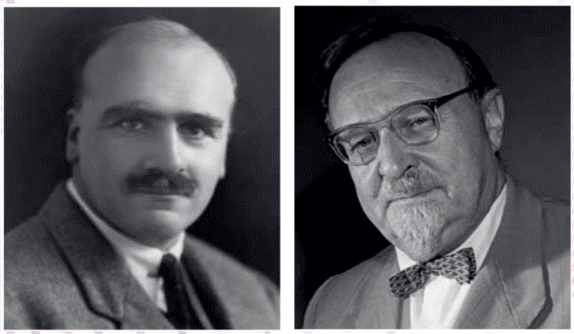


Figure 4.4 J B S Haldane and A I Oparin

Figure 4.5 Clouds of inter-stellar gas have been shown to contain organic molecules

Aleksandr Oparin, a Russian biologist who first put forward his ideas in 1924, and **John Haldane**, an English biologist independently put forward almost identical ideas in 1929 (before Oparin's book had been translated into English). Both believed that organic molecules could be formed from abiogenic materials in the presence of an external energy source such as ultraviolet

radiation and that the primitive atmosphere was reducing (having very low amounts of free oxygen) and contained ammonia and water vapour, among other gases. Both also suspected that the first life-forms appeared in the warm, primitive ocean and were heterotrophic (obtaining preformed nutrients from the compounds in existence on early Earth) rather than autotrophic (generating food and nutrients from sunlight or inorganic materials).

They proposed that common gases in the early Earth atmosphere combined to form simple organic chemicals, and these in turn combined to form more complex molecules. Then, the complex molecules became separated from the surrounding medium, and acquired some of the characters of living organisms.

Figure 4.6 Coacervate droplets – pre-cells

They became able to absorb nutrients, to grow, to divide (reproduce), and so on.

Later Miller had apparently approved the Oparin-Haldane model by mixing the basic elements to produce simple organic compounds, and then combining these to produce the building blocks of proteins andnucleicacid (Figure 4.7).

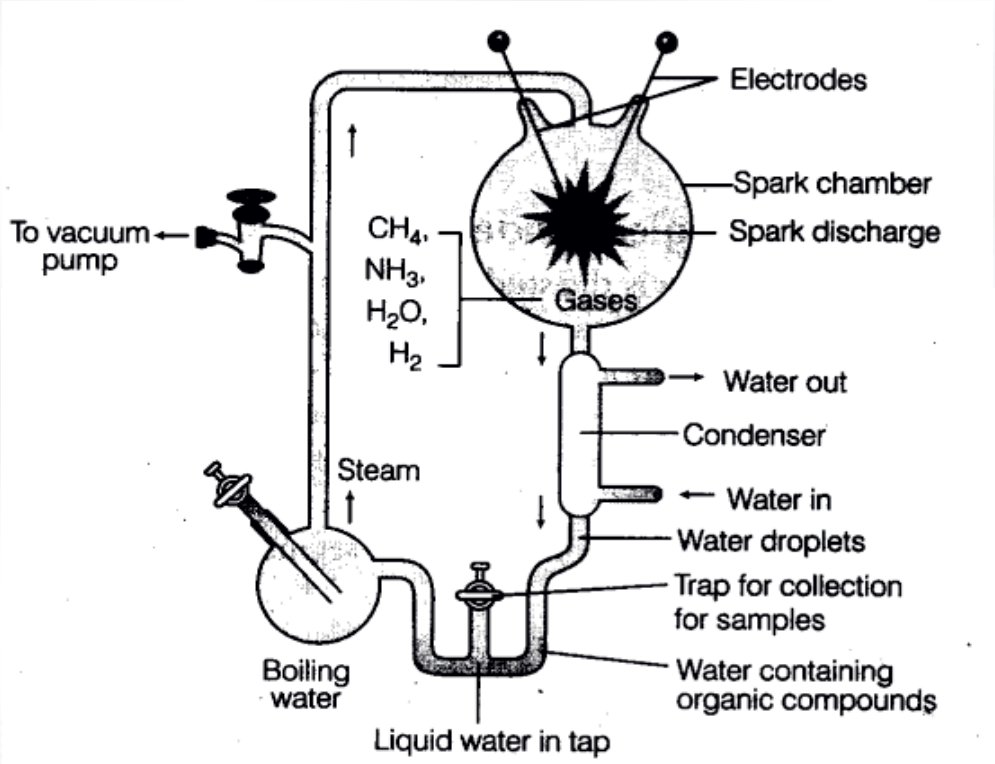


Figure 4.7 Stanley Miller's spark-discharge

Activity 4.4

Refer to different evolution books or the internet and understand the experiment done by Stanley Miller's to support the theory of biochemical origin of life. Explore also some other known scientists how they tried to generate data to support this theory. Present your finding to the class.

Autotrophs

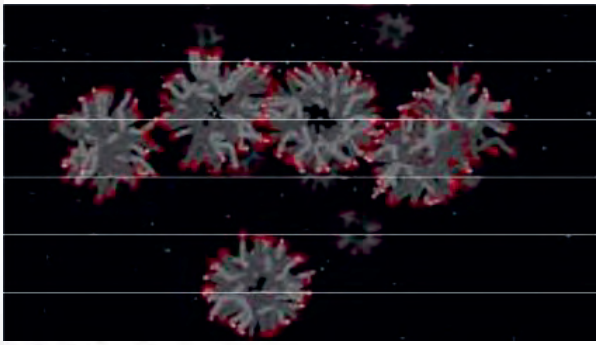
Autotrophs form the basis for all food chains: they are the organisms which create sugars, proteins, lipids, and other materials for life. The first organisms appeared about 4 billion years ago were **prokaryotes**. They had no true nucleus. It seems likely also that they had RNA rather than DNA as their genetic material. It was assumed that they gave rise to three distinct lines of evolution leading to:

- **Archaebacteria** – prokaryotes including thermophilic sulphobacteria, methanobacteria and halophilic bacteria

- **Eubacteria** – prokaryotes; ordinary bacteria and cyanobacteria (blue-green bacteria and sometimes known as blue-green algae).

- **Eukaryotes** – eventually evolving into protoctistans, fungi, plants, animals (nearly all are aerobic).

One great change that affected the evolution of early life forms was the shift from the reducing atmosphere to an atmosphere containing oxygen. This took place about 2.4 billion years ago. The two major types of autotrophs are chemoautotrophs and photoautotroph.



Self-questioning

What are chemoautotrophs? How do they differ from photoautotrophs?

Figure 4.8 Could pre-cells have looked like this when they were dividing?

Keywords

Autotrophs are organisms that produces organic molecules from inorganic material

Heterotrophs are organisms that consume producers or other consumers

Aerobic respiration is a means by which cells release energy from organic molecules using oxygen

Prokaryote is an organism consisting of a prokaryotic cell. All bacteria are prokaryotes

Eukaryote is an organism consisting of one or more eukaryotic cells. All organisms other than bacteria are eukaryotes

Archaebacterium is the first bacteria (and thus the first living organisms) to develop on Earth. They are now only found in extreme conditions

Eubacterium is any bacteria that is not an archaebacterium is a eubacterium

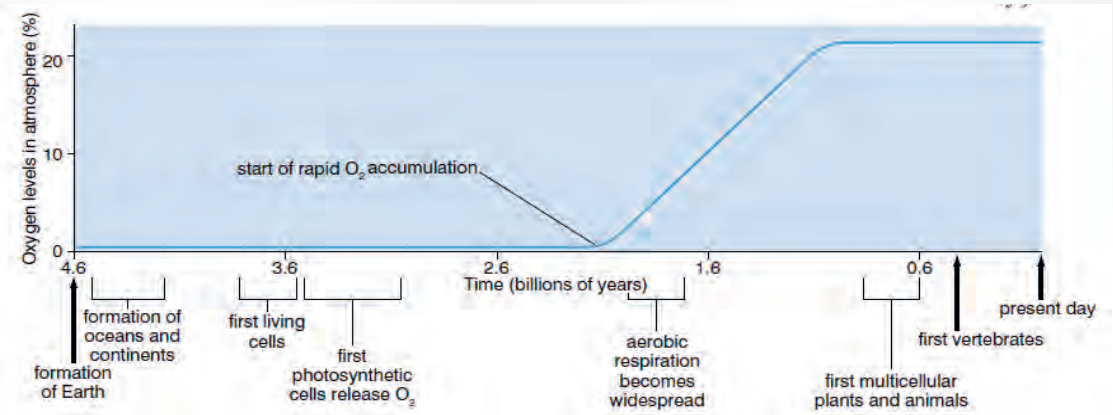


Figure 4.9 Life on Earth has evolved over billions of years

Chemoautotrophs

Chemoautotrophs are organisms that obtain their energy from a chemical reaction (chemotrophs) but their source of carbon is the most oxidized form of carbon, carbon dioxide (CO_2). The best known chemoautotrophs are the chemolithoautotrophs that use inorganic energy sources, such as ferrous iron, hydrogen, hydrogen sulfide, elemental sulfur or ammonia, and CO_2 as their carbon source. All known chemoautotrophs are prokaryotes, belonging to the Archaea or Bacteria domains. They have been isolated in different extreme habitats, associated to deep-sea vents, the deep biosphere or acidic environments. This form of energy conservation is considered one of the oldest on Earth. 0..

Photoautotrophs

Photoautotrophs are organisms that use light energy and inorganic carbon to produce organic materials. Eukaryotic photoautotrophs absorb energy through the chlorophyll molecules in their chloroplasts.

4.1.2. Theories of evolution

By the end of this section, the learner will be able to:

- Compare Lamarck Vs. Darwinian theory

Lamarckism

Jean-Baptiste De Lamarck (1744 - 1829) was a great French naturalist. Lamarck sought a naturalistic explanation for the diversity of modern organisms and the animals seen in

the fossil record. ′ He proposed 'the theory of inheritance of acquired characters' in 1809. He postulated:

A. New Needs: Changes in environment factors like light, temperature, medium, food, air etc or migration leads to origin of new needs in living organisms. To fulfil these new needs, living organisms have to exert special efforts like changes in habits or behavior.

B. Use and disuse of organs: ′ The new habits involve the greater use of certain organs to meet new needs, and the disuse or lesser use of certain other organs which are of no use in new conditions.

C. Inheritance of acquired characters: he believed that the favorable acquired characters are inheritable and are transmitted to the offsprings so that these are born fit to face the changed environmental conditions and the chances of their survival are increased.

D. Speciation: Lamarck believed that in every generation, new characters are acquired and transmitted to next generation, so that new characters accumulate generation after generation. After a number of generations, a new species is formed.

 Activity 4.5 Debating the origin of life

Your teacher will assign you to form small groups on the bases of the following theories:

- The creationists
- The spontaneous generationists
- The Eternalists
- The Cosmozoans
- The Abiogenesists

Each group must prepare a 'case' for their theory of the origin of life. Once this is done, each group will, in turn, then start a debate by announcing: This house believes that only (Creationism, for example,) can truly account for the origin of life. The group will have five minutes to put their case to the rest of the class. The group starting the debate will then face five minutes of questions from the other group members.

At the end, those members not involved directly in this debate will vote as to who they think has won the debate – the group proposing the theory or the group questioning the theory.

You must try to vote only on the debate, not on your personal views.

Keyword

Lamarckism is the theory developed by the French biologist Jean-Baptiste Lamarck that claimed that organisms passed on to subsequent generations traits acquired during their lifetime

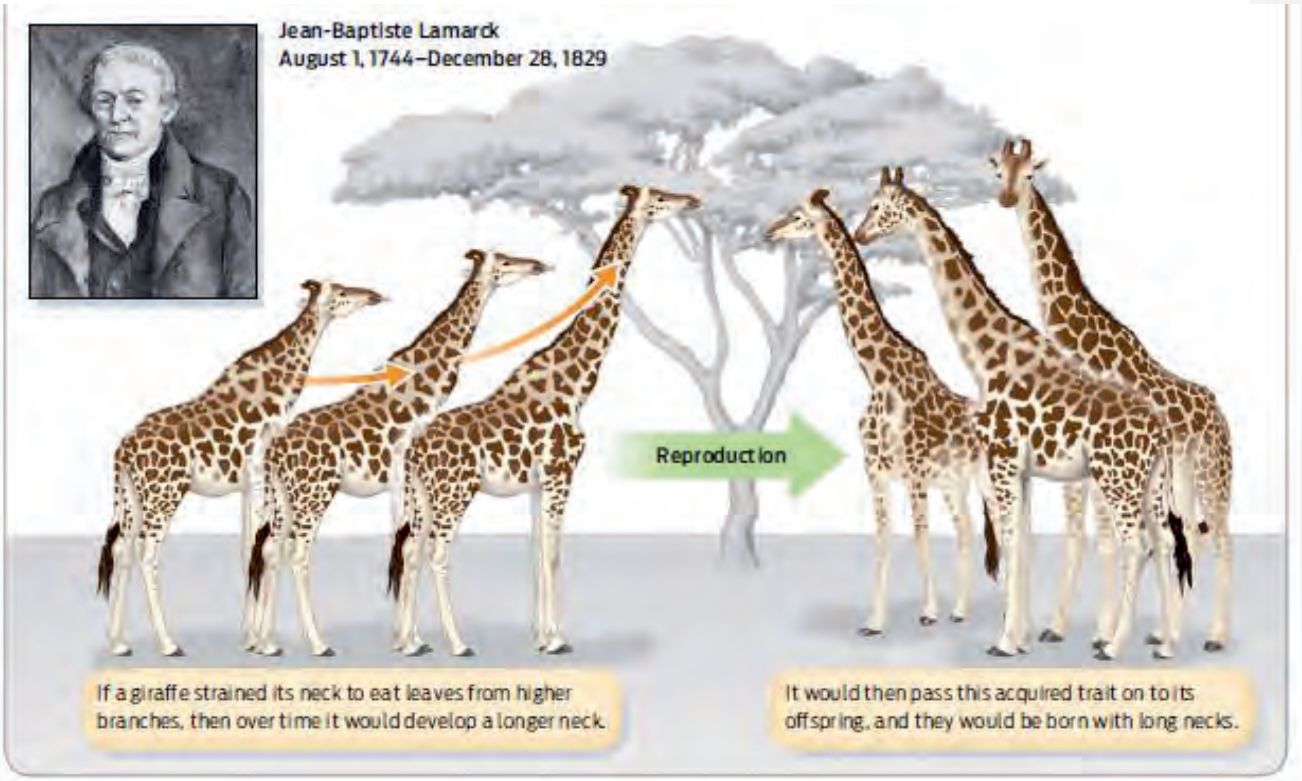


Figure 4.10 Lamarck's ideas of use and disuse and the inheritance of acquired traits

Use and disuse

In this part of his theory, Lamarck suggests that when a structure or process is continually used, that structure or process will become enlarged or more developed. Conversely, any structure or process that is not used or is rarely used will become reduced in size or less developed. The classic example he used to explain the concept of use and disuse is the elongated neck of the giraffe. According to Lamarck, a given giraffe could, over a lifetime of straining to reach high branches, develop an elongated neck. However, Lamarck could not explain how this might happen.

Inheritance of acquired traits

Lamarck believed that traits changed or acquired during an individual's lifetime could be passed on to its offspring. Giraffes that had acquired long necks would have offspring with long necks rather than the short necks their parents were born with. This type of inheritance, sometimes called Lamarckian inheritance, has since been disproved by the discoveries of genetics. However, Lamarck did believe that evolutionary change takes place gradually of evolution and constantly.

1. Significance of Lamarckism

a) It was first comprehensive theory of biological evolution.

b) It nicely explains the existence of vestigial organs in animals due to their continuous disuse. Vestigial organs are organs that are a part of the organism that are no longer in use. That can be used to determine the relatedness of different species. For example, the bone structures of the front flippers of a whale contain bones of limbs that exist in mammals such as cows.

c) It explains the development of strong jaw muscles and claws in the carnivores due to their continued extra use.

d) It stimulated other biologists to look for the mechanism of organic mechanism.

Activity 4.6

Make a small group and search for some of the evidences that were used to support Lamark's theory and the critics forwarded against this theory. Present your work to the class.

Darwinism (Theory of natural selection)

Proposed by Charles Darwin (1809-1882 A.D.), an English naturalist. He went on a voyage on H.M.S Beagle and explored South America, the Galapagos Islands and other islands. He was highly influenced by essay entitled 'On the Tendency of varieties on Depart Indefinitely from the original type'' by Alfred Russell Wallace and another essay

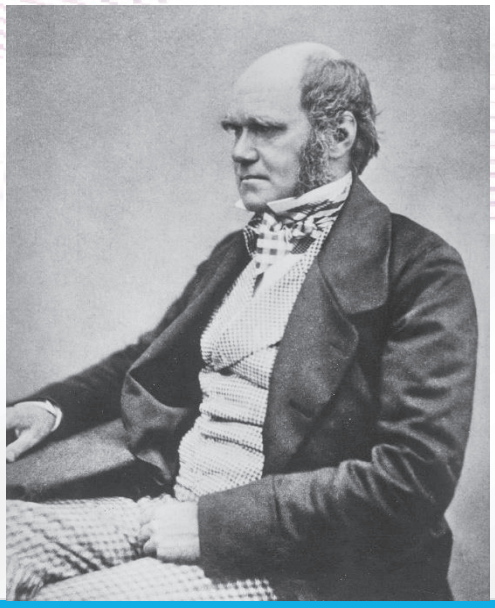


Figure 4.11 Charles Darwin

'Principle of geology'' written by Charles Lyell.

Some of Darwin's evidence came from a visit to the Galapagos Islands. These are a small group of islands in the Pacific Ocean about 600 miles off the coast of Ecuador in South America. Darwin visited five of the Galapagos Islands and made drawings and collected specimens. In particular, Darwin studied the finches found on the different islands and noted that there were many similarities between them, as well as obvious differences. He concluded that an 'ancestral finch' had colonized the islands from the mainland and, in the absence of predators, were able to adapt to the different conditions on the islands and, eventually, evolved into different species (Figure 4.12). Some of the finches had, he suggested, evolved into insect eaters, with pointed beaks. Others had evolved into seed eaters with beaks capable of crushing the seeds.

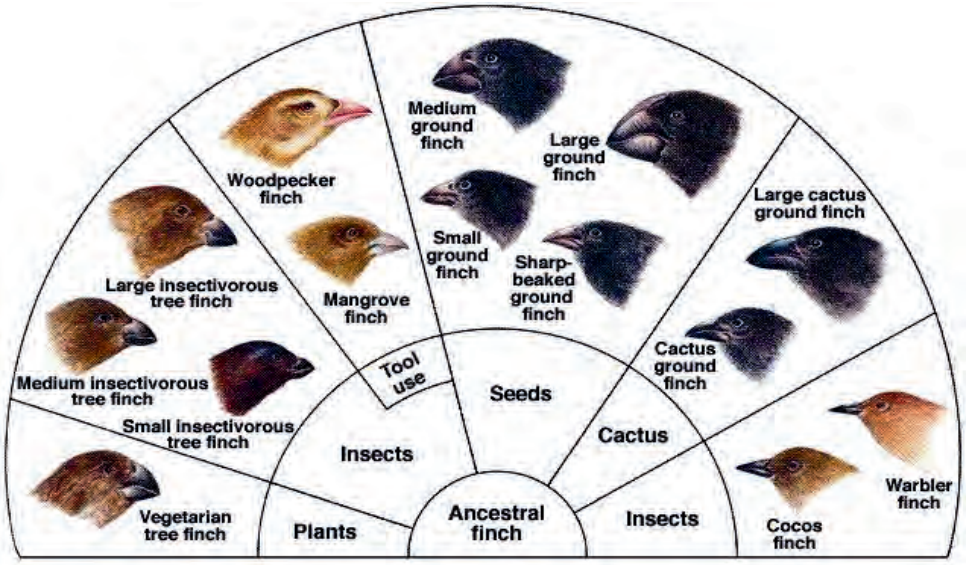


Figure 4.12 Darwin's Theory of Finches on the Galapagos Islands

Basic postulates of Darwinism

Geometric increase: All species tend to produce more offspring than can possibly survive. However, the space and the availability of food supply is limited to support the number of organisms that increase in a geometric ratio.

Struggle for existence: Since the number of individuals produced is far more than the number that can be supported, there is an everlasting competition between organisms at all levels of life.

Variation under nature: No two individuals of a species are exactly similar and they have some differences. These differences are

called variations and without evolution is not possible. Variations give rise to new characters and heredity passes them on to the next generation (inheritance of useful variations).

Natural selection or **survival of the fittest**: Due to struggle for existence and useful heritable variations, only those individuals survive which show high selective value and in the course of time they develop various adaptive modifications to suit the changed conditions of life. Such selection was called natural selection by Darwin.

Origin of species: In the course of long periods of time the best fitted and suitable individuals survived and adjust to the nature. As environment is ever changing, further changes occur and thus new adaptations appear in organisms. The later descendants after several generations become quite distinct from their ancestors. On this way new species appear.

Activity 4.7

1. Make a small group and read from different books about the evidences used to support Darwin's theory and the critics against this theory. Present your work to the class.
2. Why Darwinism theory is said to be descent with modification?
3. Explain the evolution of giraffe in the view of Darwinism and Lamarkism?

Activity 4.8

Form small groups and discuss Lamarck and Darwin theories of evolution. Prepare charts on the main points and elaborate the differences and similarities between the explanations of the two theories.

Neo-Darwinism theory

Charles Darwin knew very little of genetics. Mendel had not carried out his ground-breaking work on inheritance at the time Darwin published his book *On the Origin of Species*. However, we can now incorporate our knowledge of genes and gene action into the theory of natural selection to give a better understanding of what drives evolution.

Keyword

Neo-Darwinism a revised version of Darwin's theory of evolution by means of natural selection. This theory, which is now accepted by most biologists, combines Darwin's original theory, genetic theory and theories about animal behavior.

Genes determine features. But when we think about how a population might evolve into a new species, we need to think not just in terms of the alleles each individual might carry, but also in terms of all the alleles (all the genes) available in the population. We call this the **gene pool** of the population.

Postulates of Neo-Darwinism are:

1. Genetic variability
2. Natural selection
3. Reproductive Isolation

 Activity 4.9

Discuss in small group what Neo-Darwinism theory is and the details of the three postulates of Neo-Darwinism. Reflect your opinion to the class.

4.1.3. The evidence for evolution

 By the end of this section, the learner will be able to:

- Explain how comparative anatomy embryology, fossil records, and biochemistry provide evidence for evolution

4.1.3.1 Comparative anatomy

Comparative anatomy is one of the strongest forms of evidence for evolution. It looks at the structural similarities of organisms and uses these similarities to determine their possible evolutionary relationships. It assumes that organisms with similar anatomical features are closely related evolutionarily, and that they probably share a common ancestor. Some organisms have anatomical structures that are very similar in form, but very different in

function. We call such structures **homologous structures**. Because they are so similar, they indicate an evolutionary relationship and a common ancestor of the species. Perhaps the best-known example of homologous structures is the forelimb of mammals. When examined closely, the forelimbs of humans, whales, cats and bats are all very similar in structure (Figure 4.13).

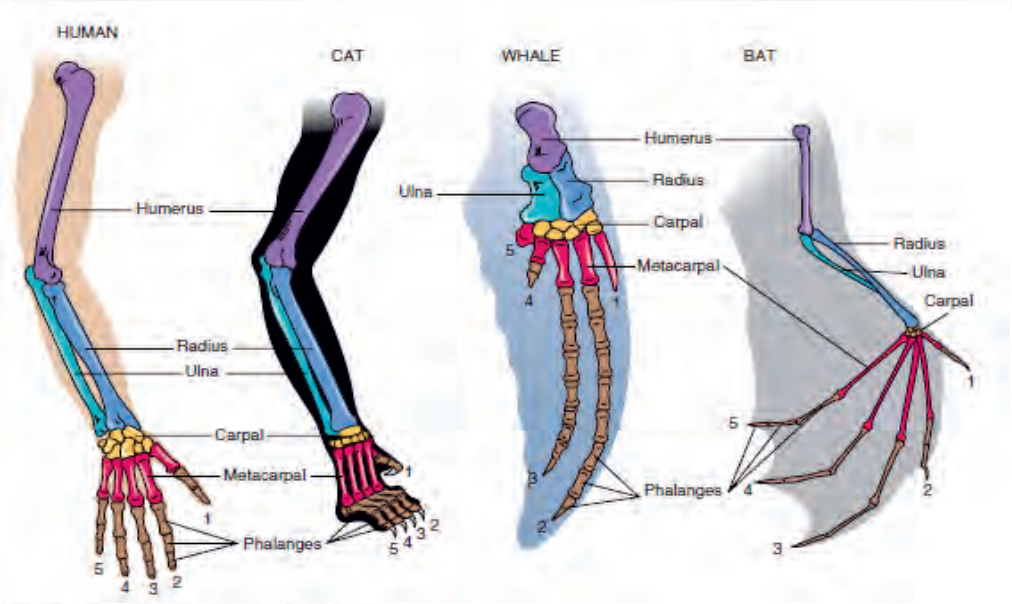


Figure 4.13 The homologous forelimbs of mammals.

Each possesses the same number of bones, arranged in almost the same way while they have different external features that function in different ways as:

- arm for manipulation in humans
- leg for running in cats
- flipper for swimming in whales
- wing for flying in bats

By comparing the anatomy of these limbs, scientists have determined that the basic pattern (called a **pentadactyl limb**) must have evolved just once and that all organisms with this kind of limb were

Keyword

Homologous structures are structures with the same basic anatomy and a common evolutionary origin but having a different function

Keywords

Pentadactyl limb is a limb with five digits

Analagous structures struactures having the same function but different anatomy and different evolutionary origin.

descended from that original type, which they share a common ancestor

However, comparative anatomy needs to be used carefully as evidence for evolution. This is because while sometimes organisms have structures that function in very similar ways, morphologically and developmentally these structures are very different. We call these analogous structures. Because they are so different structurally, even though they have the same function, they cannot indicate that two species share a common ancestor. Although, the wings of a bat, bird and mosquito all serve the same function, yet their anatomies are very different. For example, the bird wing has bones inside and is covered with feathers while the mosquito wing has neither of these (Figure 4.14). They are analogous structures that have evolved separately.

Figure 4.14 Analogy in animals

Activity 4.10

Discuss in small group and explain why homology implies identity and anologus implies similarity. Reflect your opinion to the class.

4.1.3.2 Embryology

Comparative embryology studies the way in which the embryos of vertebrates develop before they hatch or born. This development shows similarities which supports a common ancestry.

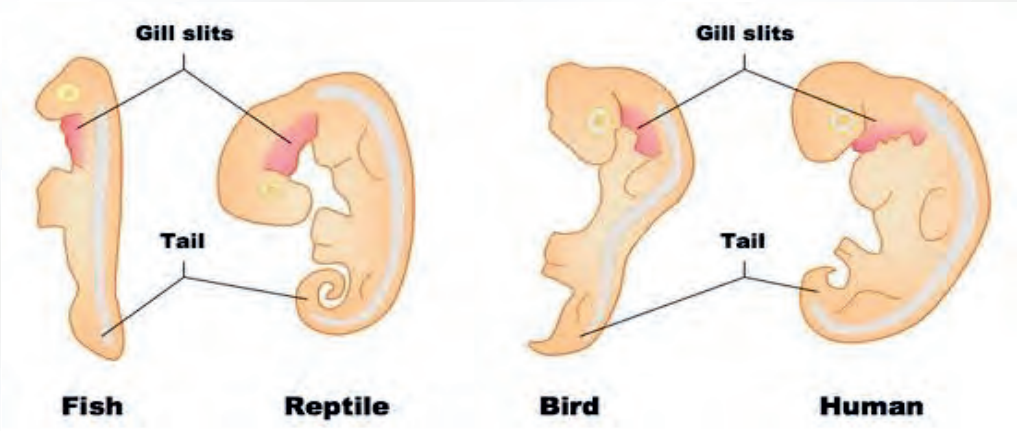


Figure 4.15 Similarities in development of embryos.

For example early in development, all vertebrate embryos have gill slits and tails (Figure 4.15). However, the 'gill slits' are not gills; they connect the throat to the outside, but in many species they disappear later in the embryonic development. However, in fish and larval amphibians they contribute to the development of gills.


Activity 4.10

Form a small group and discuss on the following question:

- Do you think an embryo retraces its evolutionary history? Reflect on how it does to the class.

The embryonic tail does not develop into a tail in all species. In humans, it is reduced during development to the coccyx, or tailbone. The more similar the patterns of embryonic development, the more closely related species are assumed to be. The similarity in the development of vertebrates also suggests a common ancestor.

4.1.3.3 Palaeontology (Paleontology)

The study of fossils is known as **palaeontology**. Fossils are formed when certain remains of organisms or plants get embedded in the soil or water and are preserved for many hundreds of years. They appear either as skeletal remains, footprints, moulds or intact structures as found in the snow. By studying fossils, we are able to establish similarities between the organisms in the present to its ancestor in the past. There can be many similarities that prove the common origins between different closely

related animals and the differences can be studied to establish how they differ now and why. Fossils are very important evidence to prove the theory of evolution and common ancestry. We can group fossils into two categories:

Category 1: The remains of dead animals or plants or the imprint left from the remains, including:

- bones
- teeth
- skin impressions
- hair
- the hardened shell of an ancient invertebrate
- such as a trilobite or an ammonite

an impression of an animal or plant, even if the actual parts are missing

Category 2: Something that was made by the animal while it was living and that it has hardened into stone since then; these are called trace fossils and include:

- footprints
- burrows
- coprolite

(animal faeces)

Self-questioning

How do fossils form?

Type I fossils can be the actual organism or part of an organism, like a piece of bone or hair or feather as it actually was. For example, this spider (Figure 4.17) has been trapped, completely unchanged, inside the amber for millions of years. Amber is fossilised resin from trees. This spider probably became stuck inside the sticky resin and could not escape. As the amber .became fossilised, the spider was protected from micro-organisms and the air which would have led to its decomposition. In many fossils like this, the soft parts of the body have been lost, but the exoskeleton is perfectly preserved. In some cases, however, the entire body remains.

Figure 4.16 A spider preserved in amber.

Dating fossils

Sedimentary rocks are laid down in layers (strata) which help to deduce how the organisms have changed over time. This is called **stratigraphy**. The oldest strata and the oldest fossils are found in the lowest layers and more recent rocks and fossils in

the layers above them nearest to the surface (Figure 4.17). The thickness of each stratum (shown in the diagram) is a measure of the time period during which that stratum was formed.

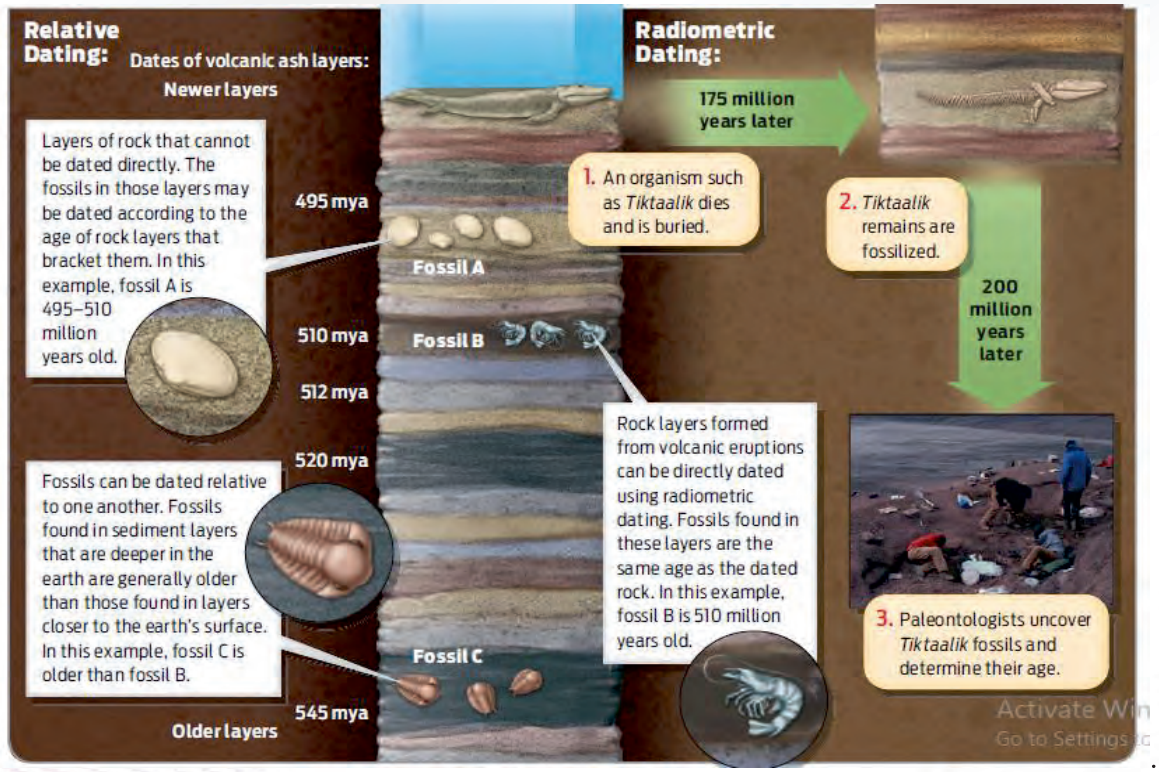


Figure 4.17 Stratigraphy and the how the relative age of fossils dated.

Activity 4.11

Refer from books and other sources how scientists actually date rocks? How do they find out how old each layer is? What does half-life time is? Reflect your answer to the class.

Some minerals in rocks and organic matter (e.g., wood, bones, and shells) can contain radioactive isotopes. The abundances of parent and daughter isotopes in a sample can be measured and used to determine their age. This method is known as **radiometric dating**. The amount of time it takes for half of the parent isotopes to decay into daughter isotopes is known as the **half-life** of the radioactive isotope (Figures 4.18). Fossil age can be determined using two ways; absolute dating which determines the number of years that have elapsed since an event occurred or the specific time when that event occurred. On the other hand, relative dating

determines the age by analyzing rocks and structures placed into chronological order, establishing the age of one thing as older as or younger than another.

Keyword

Half-life: the time needed for half the atoms of a radioactive substance to decay. After two half-lives, three quarters of the atoms will have decayed, and so on.

Fossils: the preserved remains or impressions of once-living organisms.

Fossil record: An assemblage of fossils arranged in order of age, providing evidence of changes inspecies over time.

Paleontologist: A scientist who studies ancient life by means of the fossil record

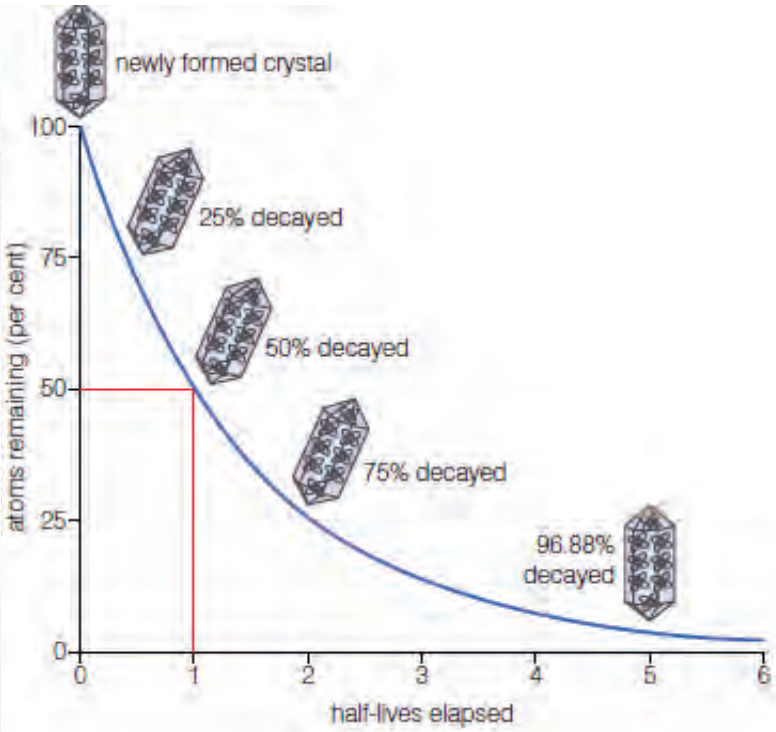


Figure 4.18 Half-life of a radioactive element

Activity 4.12

Discuss about fossils found in Ethiopia and explain why these fossils are thought to be so important? Report your finding to the class.

At time zero, the sample is composed entirely of the radioisotope (Figure 4.19) and the radioactive clock begins ticking. After one half-life, only 50% of the original radioisotope remains. During each succeeding half-life, half of the remaining radioisotope is converted to decay product (s).

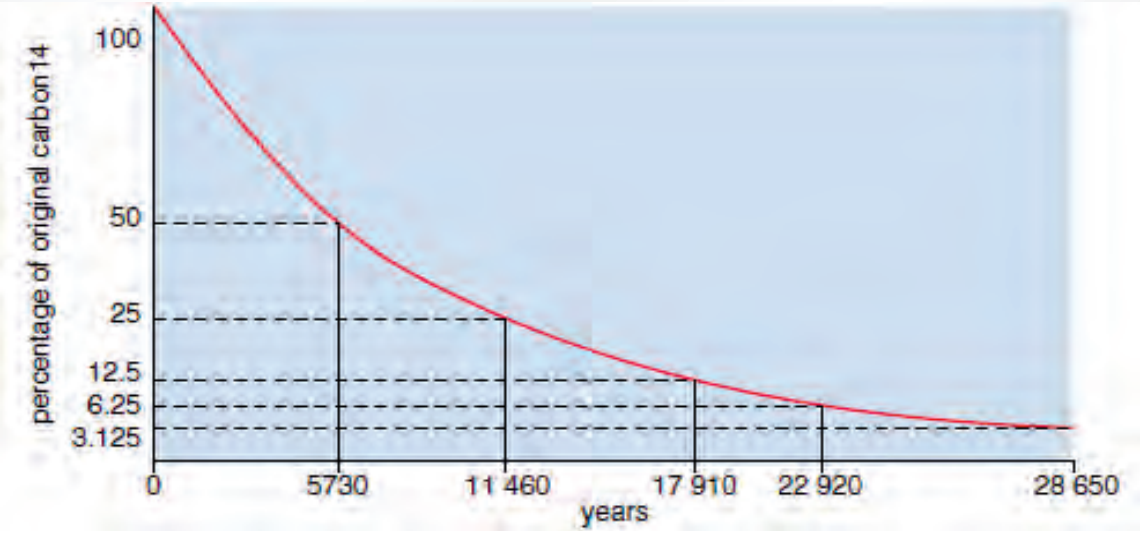


Figure 4.19 Converting the percentage of carbon 14 in a fossil to an age.

How do scientists actually date the rocks? How do they find out how old each layer is? To do this, we scientists use one of two techniques:

- Radiocarbon dating, or
- Potassium–argon dating.

Both these techniques rely on the principle that radioactive atoms decay into other atoms over time. Radioactive carbon atoms (C14) decay into non-radioactive nitrogen atoms (N). Radioactive potassium atoms (K40) decay into argon atoms (A40). Each has what is known as a **half-life**. During this period, half of the radioactive atoms decay. So, starting with a certain number of radioactive potassium atoms, after one half-life, 50% will still be radioactive. After a second half-life, 50% of this will have decayed and 25% of the original number will still be radioactive

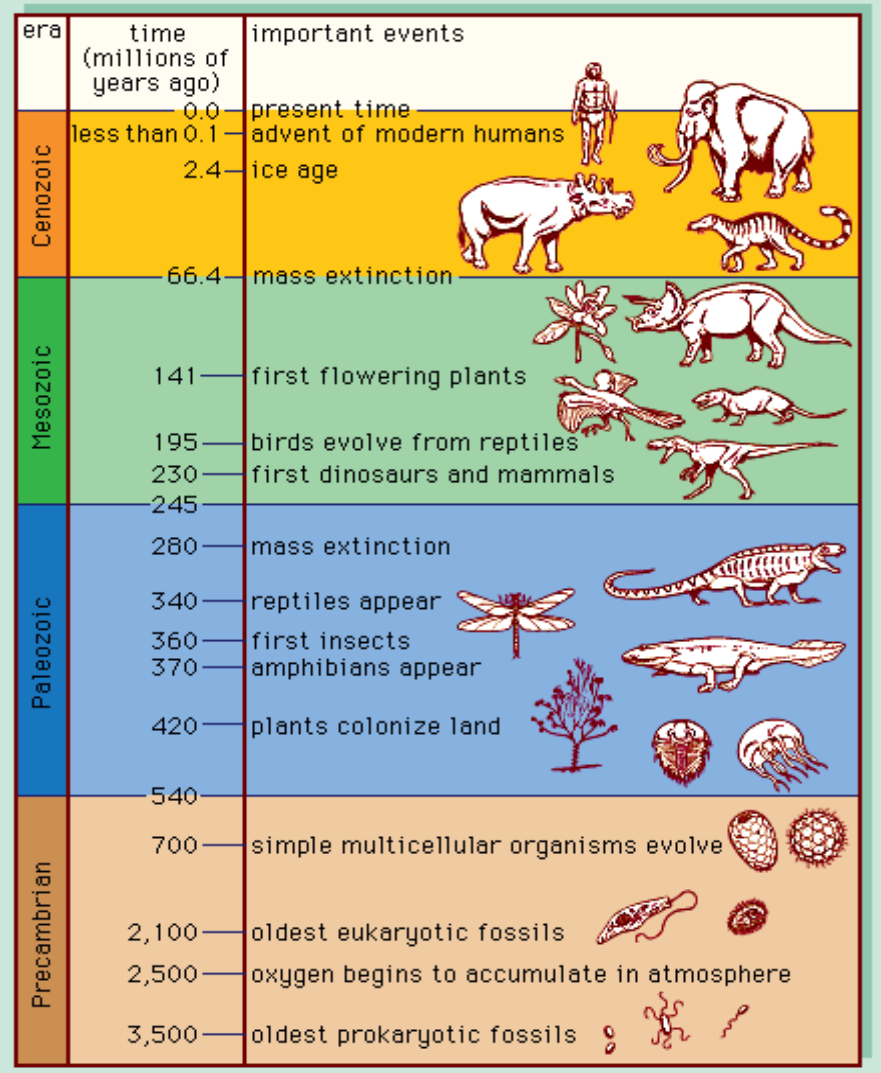


Figure 4.20 Key events in the fossil record of animal evolution

4.1.3.4 Comparative biochemistry

Organisms that share very similar molecules and biochemical pathways are closely related evolutionarily. Chemicals that have been used in such analysis include DNA protein.

Species that are closely related are believed to have the most similar DNA and proteins; those that are distantly related are assumed to share fewer similarities. For example, a comparison of DNA sequences shows that 98% of our DNA is the same as chimpanzees which confirms that chimpanzees are the closest relatives of humans (Figure 4.21).

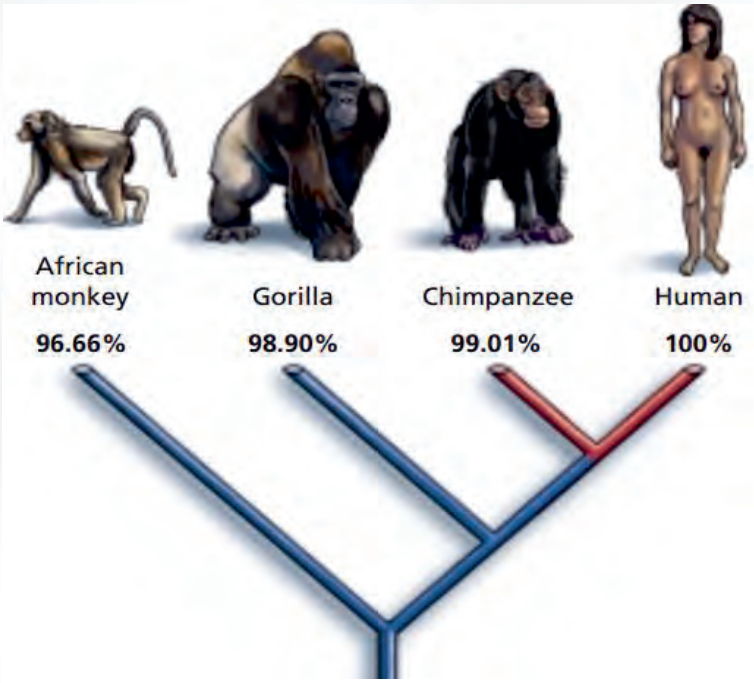


Figure 4.21 A phylogenetic (evolutionary) tree of some animals based on differences in DNA

The **haemoglobin** molecule is similar in all animals that possess it, but there are differences. For example, the haemoglobin of the lamprey (a primitive fish-like animal) has only one polypeptide chain, not four. Most animals have haemoglobin with four chains, but the chains do vary. Figure 4.22 shows the differences in the amino acid sequences of the α chains of haemoglobin of the human and several other animals. The diagram (Figure 4.22) is presented to show how different animals may have diverged from the evolutionary line that led to humans.

Keyword

Hemoglobin is the molecule found in red blood cells that carries oxygen to where it is needed

Table 4.1 Similarities and differences between the polypeptide chains of hemoglobin in four primate species

Species	Alpha-hemoglobin (141 amino acids)	Polypeptides chains Beta-hemoglobin (146 amino acids)	Y-hemoglobin
Human	+	+	+
Chimpanzee	+	+	+
Gorilla	1	1	1
Gibbon	3	3	2

Key: Hemoglobin is composed of four peptide chains, made up of alpha, beta, and gamma (Y) polypeptides.

+ indicates no differences in amino acids sequence from that of human, figures indicates number of amino acid differences.

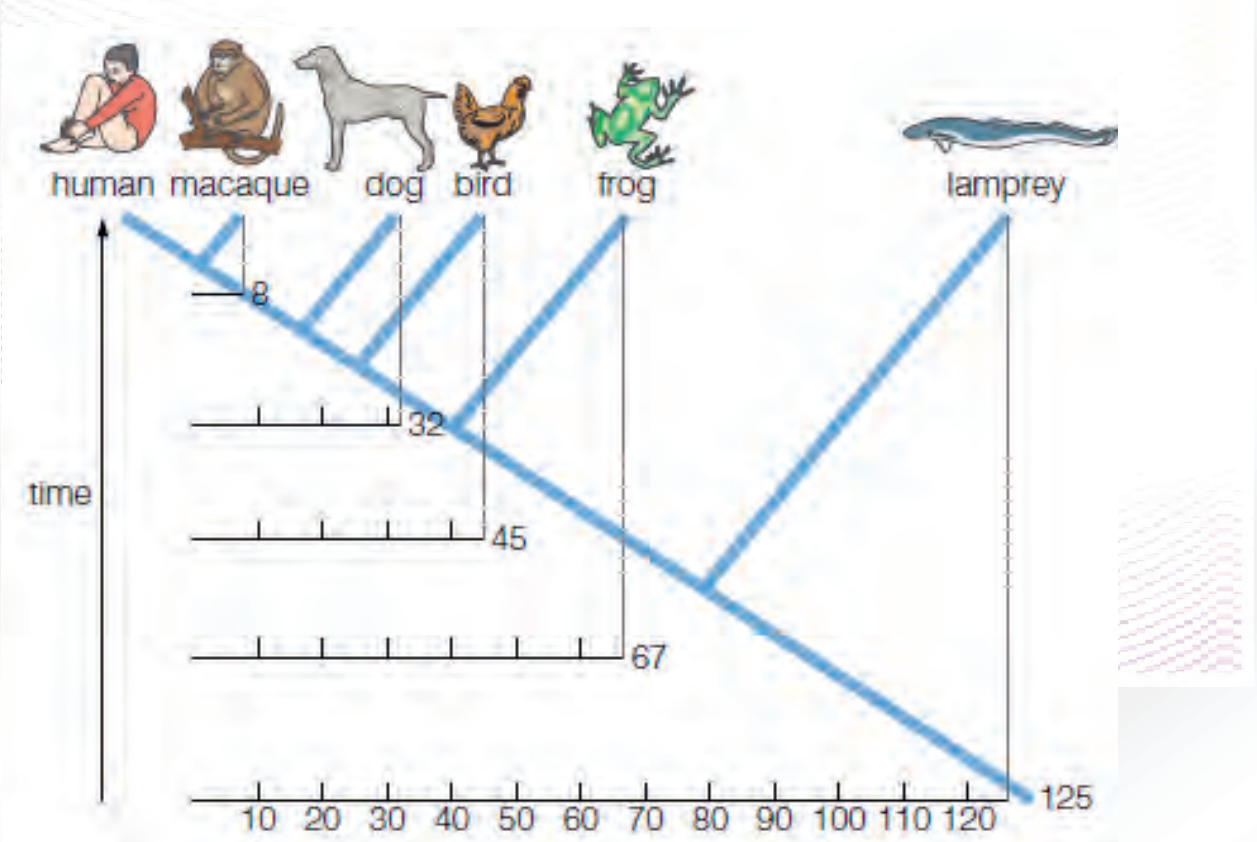


Figure 4.22 The evolutionary relationships of some animals shown by differences in haemoglobin

The molecules that are used to show evolutionary relationships are those that are common to large numbers of organisms. But, clearly, haemoglobin analysis cannot be used to include plants and algae in any phylogenetic tree.

Activity 4.13: The evidence for evolution

Your Teacher will divide the class into groups with the following professions

- The Palaeontologists
- The Anatomists
- The Embryologists
- The Biochemists

Each group will:

- Focus on its own particular area of expertise and try to find four or five pieces of evidence from books in library/ the internet about the pieces of evidence that supports the theory of evolution
- Make a poster of their findings for display

4.1.4. Natural selection: Definition, Types & Examples

By the end of this section, the learner will be able to:

- Define natural selection
- Describe the types of natural selection with examples
- Apply the theory of natural selection in their day-to-day life (survival of the fittest)
- Appreciate the struggle among organisms for survival

Natural selection is the 'driving force' behind evolution. It is the process that brings about changes (over time) in populations that can, eventually, lead to different populations of the same species to become different species. Those members of a species which are best adapted to their environment will survive and reproduce in greater numbers than others that are less well adapted. They will pass on their advantageous alleles to their offspring and, in successive generations, the frequency of these alleles will increase in their gene pool. The advantageous types will, therefore, increase in frequency in successive generations.

Activity 4:14

1. Why natural selection is a key force for ADAPTATION?
2. How natural selection operates on the phenotype of population?
3. Give practical examples for the different types of selections

To appreciate how natural selection can eventually lead to **speciation** (the formation of new species), we must be clear what do we mean by the term species. Obviously humans are different species from chimpanzees. But, the different races of humans are all members of the same species. Why?

Our current definition of species is therefore, is a group of similar organisms with a similar biochemistry, physiology and evolutionary history that can interbreed to produce fertile offspring.

This explains why all humans are members of the same species, but belongs to a different species from the chimpanzee. So how can there be different types of natural selection? All types of natural selection work in the same manner, but their influence on a population is different. The different types of

natural selection include:

Activity 4:15

Read about natural selection and discuss in detail the following points:

a. Directional selection?

b. Stabilising selection

c. Disruptive selection

- directional selection
- stabilising selection and
- disruptive selection

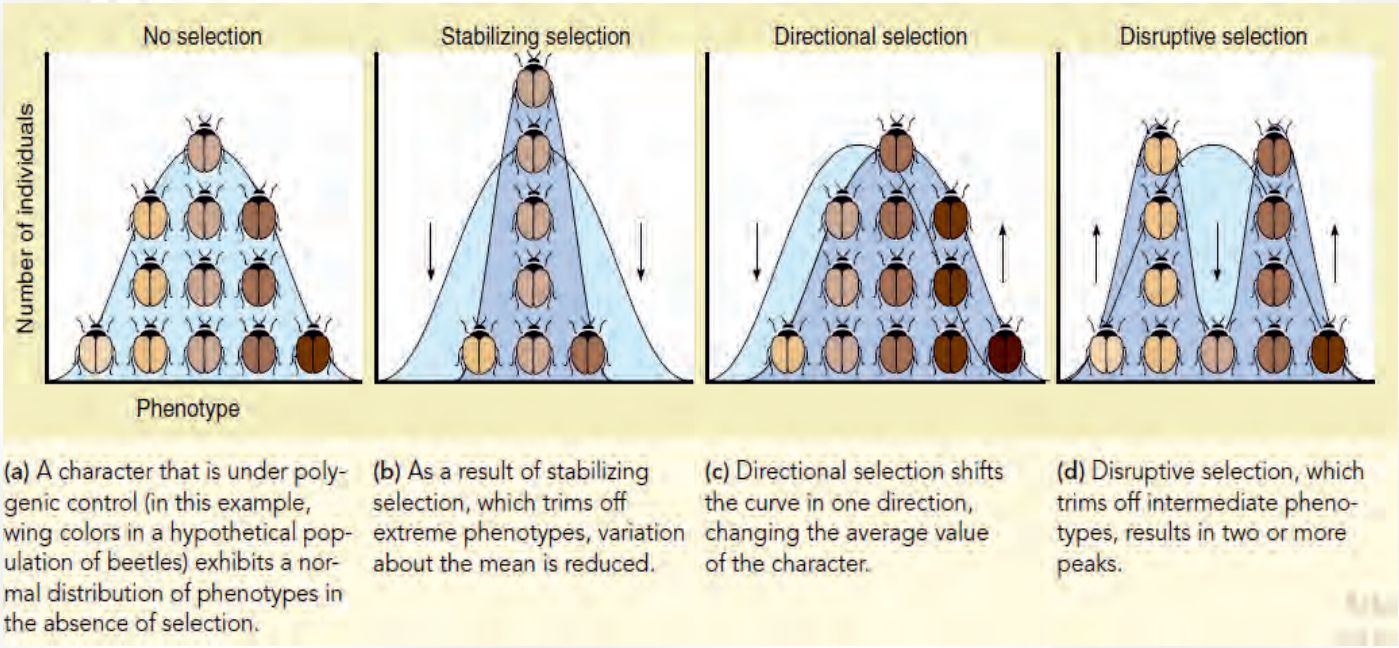


Figure 4.23 A summary of the different types of natural selection

Activity 4.16

Your teacher will facilitate to visit nearby natural forests or grasslands. You are expected to plan and inquire questions and observe what happens with the plants and animals and come up with concluding remarks on concepts like natural selection and

Antibiotic resistance – a modern example of natural selection in action

The spread of antibiotic resistance in pathogenic bacteria is a simple and elegant example of evolutionary adaptation by natural selection. Bacteria can become resistant to antibiotics through mutations that alter the cellular targets of antibiotics. The acquisition of resistance is a very rare event; for example, resistance mutations usually occur in less than 1 in a million bacteria. However, resistant bacteria can continue to grow and reproduce under antibiotic treatments that effectively paralyse or kill their antibiotic susceptible neighbours (Figure 4.24) – this is Darwinian natural selection in its simplest form.

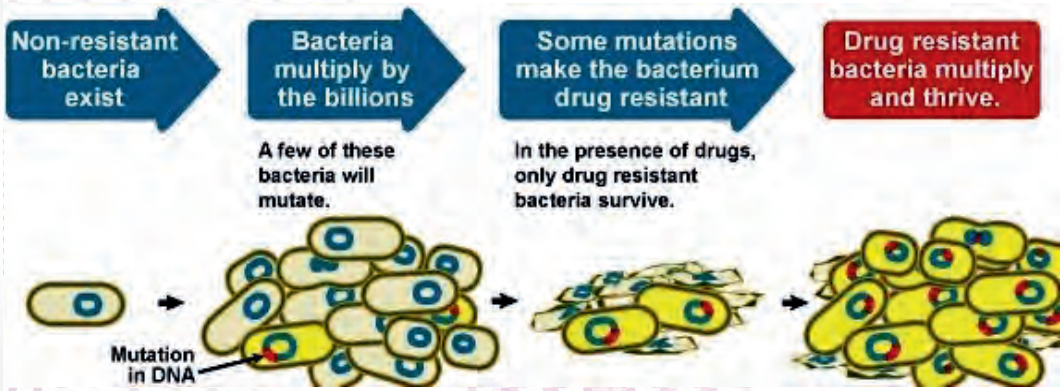


Figure 4.24 Drug resistance in bacteria is often the result of a genetic mutation

Pattern of evolution

Divergent, convergent, and parallel evolution Evolution over time can follow several different patterns. Factors such as environment and predation pressures can have different effects on the ways in which species exposed to evolve. There are three main types of evolution: divergent, convergent, and parallel evolution (Figure 4.25).

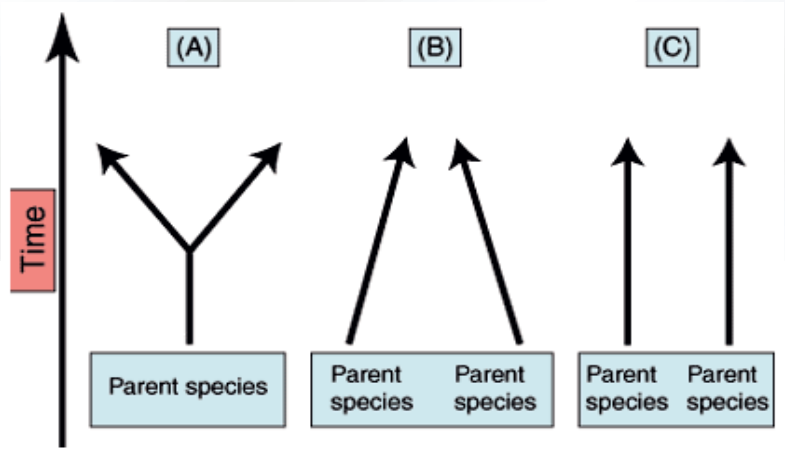


Figure 4.25 Types of evolution; A) Divergent B) Convergent C) Parallel

Divergent Evolution

When people hear the word "evolution," they most commonly think of divergent evolution, the evolutionary pattern in which two species gradually become increasingly different. This type of evolution often occurs when closely related species diversify to new habitats. On a large scale, divergent evolution is responsible for the creation of the current diversity of life on earth from the first living cells. On a smaller scale, it is responsible for the evolution of humans and apes from a common primate ancestor.

Convergent Evolution

Convergent evolution takes place when species of different ancestry begin to share **analogous traits** because of a shared environment or other selection pressure. For example, whales and fish have some similar characteristics since both had to evolve methods of moving through the same medium: water.

Parallel Evolution

Parallel evolution occurs when two species evolve independently of each other, maintaining the same level of similarity. Parallel evolution usually occurs between unrelated species that do not occupy the same or similar niches in a given habitat.

Types of speciation

Natural selection provides a mechanism by which new populations of a species can arise. But, at what point can these populations be considered as distinct species?.

Activity 4:17

1. What is a species?

2.What is the difference between reproduction and speciation?

3.How evolution plays part in the process of speciation?

4.Explain the difference between allopatric and sympatric speciation?What key elements are involved in allopatric and sympatric speciation process?

If two populations become so different, individuals from these different populations cannot interbreed to produce fertile offspring, then we must think of them as different species. There are a number of ways in which this can occur. The two main ways are:

- Allopatric speciation and
- Sympatric speciation.

Keywords

Allotropic speciation occurs when a population from an existing species becomes geographically isolated and the isolated population develops into a new species

Sympatric speciation occurs when a population from an existing species develops into a new species without becoming geographically isolated from other members of the original species.

As long as two populations are able to interbreed, they are unlikely to evolve into distinct species. They must somehow go through a period when they are prevented from interbreeding. Both allopatric and sympatric speciation involves isolating mechanisms that prevent different populations from interbreeding for a period of time (Figure 4.26). During this period, mutations that arise in one population cannot be passed to the other. As a result of this, and the different selection pressures in different environments, genetic differences between the two populations increase. Eventually, the two populations will become so different that they will be unable to interbreed or they are 'reproductively isolated'.

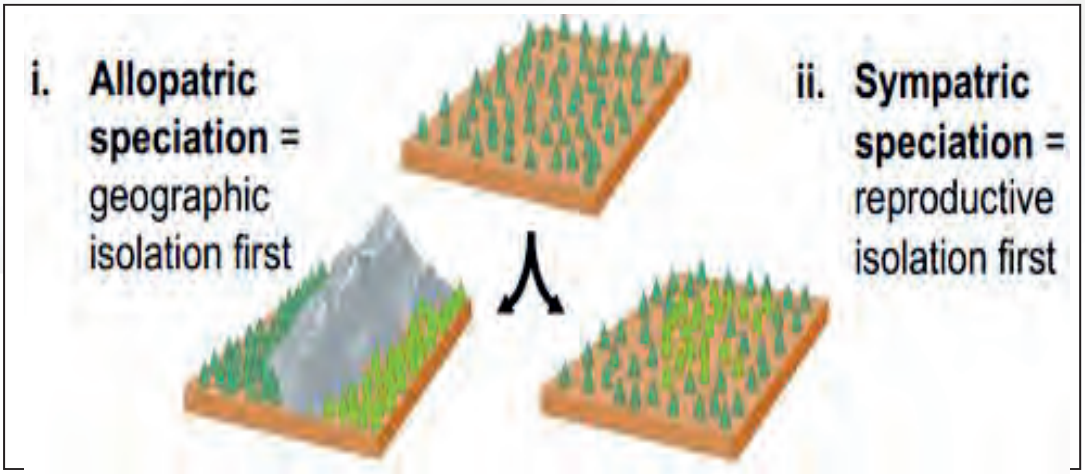


Figure 4.26. The difference between Allopatric and Sympatric speciation

Activity 4.18

- Search from books or other sources about allopatric and sympatric speciation. Write a report and present to the class.

Keywords

Polyploidy occurs when an organism has more than two sets of homologous chromosomes

Tetraploid: a tetraploid organism has four sets of homologous chromosomes

What is polyploidy and why is it important in plant evolution?

Poly- means many. **Polyploid** cells have many sets of chromosomes per cell – sometimes four sets, sometimes eight or more. Some human liver cells have 92 chromosomes per cell – they are **tetraploid** and have four sets of chromosomes per cell.

Polyploidy has been important in plant evolution because it has allowed infertile hybrids to become fertile. When different species form hybrids, very often the hybrid cannot produce offspring because all the chromosomes cannot form bivalents (homologous pairs) in meiosis. So, they cannot form sex cells and cannot reproduce. If the chromosome number were to double, then all chromosomes would be able to form homologous pairs. Meiosis and sex-cell formation can take place and the hybrid is now fertile.

Keywords

Divergent evolution –the evolution from one species of animals or plants of a number of different forms

Convergent evolution—the development of superficially similar structures in unrelated organismds, usually because the organisms live in the same kind of environment

Parallel evolution-the development of related along similar evolutionary passes due to strong selection pressures acting on all of them in the same way

A new species forms when one portion of a population can no longer breed and produce fertile offspring with the rest of the population. That is, the two separate groups no longer share a gene pool, and each begins to follow its own, independent evolutionary path. Two parts of a population can become reproductively isolated in many ways, because successful reproduction requires so many complex events. Any interruption in courtship, fertilization, embryo formation, or offspring development can be a reproductive barrier. Reproductive isolating mechanisms fall into two major categories: **prezygotic reproductive barriers** act *before* fertilization to prevent individuals of different species or populations from mating, whereas **postzygotic reproductive barriers** act *after* fertilization to prevent the development of viable offspring, or to reduce the offsprings' fertility.

Reproductive Isolation

Reproductive Isolating Mechanisms

Prezygotic barriers prevent fertilizatio

Mechanisms of **prezygotic reproductive isolation** affect the ability of two species to combine gametes and form a zygote. These reproductive barriers include the following

Ecological (or habitat) isolation: A difference in habitat preference can separate two populations in the same geographic area. For example, one species of ladybird beetle eats one type of plant, while a closely related species eats a different plant. The two species never occur on the same host plant, although they interbreed freely in the laboratory. The different habitat preferences are the reproductive barrier that keeps the gene pools of the two species separate.

Temporal isolation: Two species that share a habitat will not mate if they are active at different times of day or reach reproductive maturity at different times of year

Behavioral isolation: Behavioral differences may prevent two closely related species from mating. The males of two species of tree frogs, for instance, use distinct calls to attract mates. Female frogs choose males of their own species based on the unique calls. Likewise, sexual selection in many birds is based on intricate mating dances

Mechanical isolation: In many animal species, male and female parts fit together almost like a key in a lock. Any change in the shape of the gamete-delivering or –receiving structures may prevent groups from interbreeding. In plants, males and females do not copulate, but mechanical barriers still apply

Gametic isolation: If a sperm cannot fertilize an egg cell, then no reproduction will occur. For example, many marine organisms, such as sea urchins, simply release sperm and egg cells into the water. These gametes display unique surface molecules that enable an egg to recognize sperm of

Keywords

Prezygotic Barriers - Prevent fertilization

Temporal isolation - Similar species reproduce at different times

Habitat isolation - Similar species reproduce in different habitats

Behavioral isolation - Similar species have distinctive courtship behaviors Mechanical isolation - Similar species have structural differences in their reproductive organs

Gametic isolation - Gametes of similar species are chemically incompatible

Postzygotic Barriers- Reduce viability or fertility of hybrid

Hybrid inviability - Interspecific hybrid dies at early stage of embryonic development

Hybrid sterility - Interspecific hybrid survives to adulthood but is unable to reproduce successfully

Hybrid breakdown - Offspring of interspecific hybrid are unable to reproduce successfully

the same species. In the absence of a "match," fertilization will not occur, and the gene pools will remain separate.

Activity 4:19

Make a small group to discuss and reflect the following question

What difference have you seen between

A. temporal and habitat isolation

B. Gametic and mechanical isolation

Postzygotic Barriers Prevent Viable or Fertile Offspring

Individuals of two different species may produce a hybrid zygote.Even then, **postzygotic reproductive isolation** may keep the species separate by selecting against the hybrid offspring, effectively preventing genetic exchange between the populations. Collectively, these postzygotic barriers are sometimes called hybrid incompatibility.

Postzygotic reproductive barriers include the following:

Hybrid inviability: A hybrid embryo may die before reaching reproductive maturity, typically because the genes of its parents are incompatible. Since the hybrid offspring cannot reproduce, the gene pools of the parent species remain isolated from one another.

Hybrid infertility (sterility): Some hybrids are infertile. A familiar example is the mule, a hybrid offspring of a female horse and a male donkey. Mules are infertile because a horse's egg has one more chromosome than a donkey's sperm cell. The animal can grow and develop, but meiosis does not occur in the mule's germ cells because the chromosomes are not homologous

Activity 4.20

Make a small group and discuss

- What would happen if a muel interbreed with horse and/or donkey and produce a viable offspring? Reflect your discussion to the class.

Hybrid breakdown: Some species produce hybrid offspring that are fertile. When the hybrids reproduce, however, their offspring may have abnormalities that reduce their fitness. Some second-generation hybrid offspring of the mosquito species *Aedes aegypti* and *Aedes mascarensis*, for example, have abnormal genitalia that make mating difficult. The strong selective pressure

against hybrid offspring limits gene flow between the two mosquito species.

Activity 4.21: Apes to humans

Make a small group and discuss a topic from the list below:

- Tools and tool use by early hominids before Homo sapiens
- Who's who on the *Homo sapiens* evolutionary tree
- The preservation of non-human primates in the wild
- The common ancestor of humans and chimpanzees

 Activity 4.22 Making a fossil

You will need:

- light plastic container to make the fossil
- a sponge; natural and synthetic are both fine, but sponges with more holes work better
- some fine sand, enough to half fill your container
- magnesium sulphate
- a saucer or small tray

Carry out the following:

- Create a shape for your fossil by cutting it out from the sponge – it could be a leaf, a shell, a bone or a whole animal.
- Cut two or three small holes in the bottom of your container. Place it on the saucer/ tray.
- Put sand in the container to a depth of 1 cm.
- Place your sponge shape on top and cover with another 2 cm of sand.
- Mix four spoons of bath magnesium sulphate and warm water and pour into your container.
- Allow the mix to sink through the sand then leave it somewhere safe and warm (for example, a window ledge).
- Add more of the water and salt mix at least once a day for at least five days. The longer you leave it the more 'fossilized' it becomes! (The holes in the sponge trap the salts, mineralising the sponge; as they dry out they solidify to create a fossil. How crumbly this fossil is depends on the consistency of your local sand)
- After this time, leave the sand to dry out for two days before removing the 'fossil' sponge. If it is still a little wet, leave the fossil for a few days before

4.1.5. Human evolution

By the end of this section, the learner will be able to:

- Outline human evolution.
- State the role of paleontological discoveries in Ethiopia in explaining human evolution e.g. Lucy (*Australopithecus afarensis*).

Who are we and where have we come from?

Activity 4.23

Make a small group, and use internet, pictures, diagrams, and video material on human evolution. Reflect your findings to the class.

There is often a lot of very loose language used in describing human evolution. You will hear people say 'we evolved from monkeys' or 'we evolved from apes' or 'we evolved from chimpanzees'. None of these statements are accurate. There has been a 'line of evolution' for millions of years that has given rise to old world monkeys, new world monkeys, the great apes and the different species of humans that have lived (Figure 4.27) But, we are *Homo sapiens* and we are the latest of several humans to live on the planet.

We have two features in particular that distinguish us from other primates. These are:

- A very large brain, and
- Bipedalism – the ability to truly walk on just two legs.

There was a lot of debate amongst biologists as to which of these came first and also about exactly how this 'evolutionary tree' (Figure 4.27) has given rise to the various groups although they may disagree.

Keyword

Homo sapiens is the species that all humans alive today belong to.

Activity 4.24

Form small groups and discuss differences among the human races.

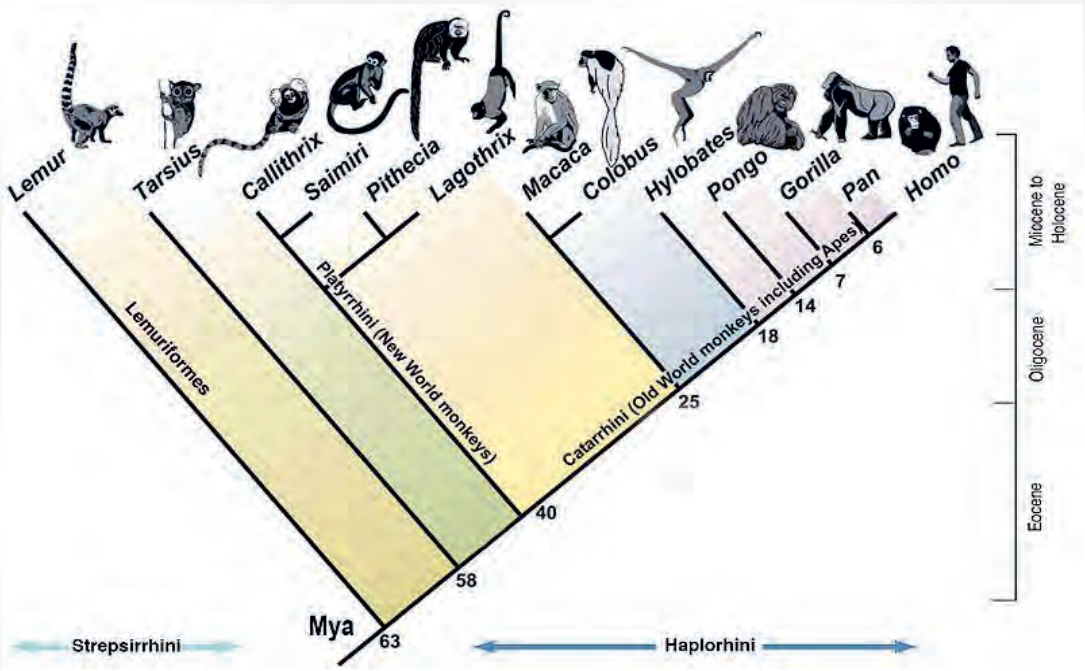


Figure 4.27 The evolutionary tree for modern primates

Over the details, they all agreed about the idea – a line evolution that has branched to give the different groups of primates (including apes and humans) that exist today has existed in not too distant past. Figure 4.28 shows the part of the evolutionary tree of humans and the living great apes in more detail.

Keywords

Genus (plural **genera**) a group of closely related species

Hominin any member of the genus Homo. This includes modern humans (Homo sapiens), neanderthals and Homo erectus

Hominid a group of species that includes all the species belonging to the genus Homo along with other species such as Ardipethecus ramidus and Australopithecus afarensis (Lucy).

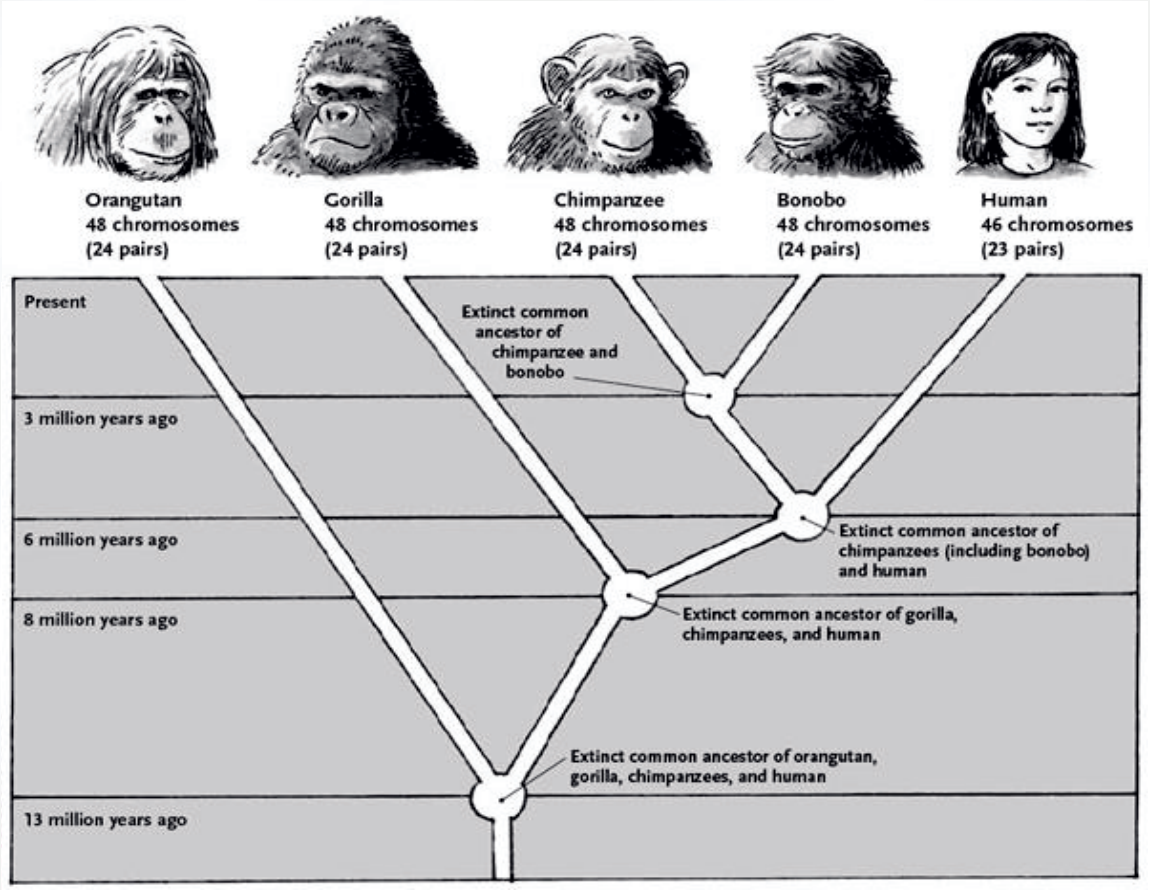


Figure 4.28 The evolutionary tree of humans and the great apes

Branching points in the evolutionary tree represent ancestors (Figure 4.28). At these points it is assumed that an ancestral type became divided into at least two populations which subsequently evolved along different lines. For example, humans and chimpanzees both evolved from a common ancestor that lived about 6 million years ago (Figure 4.28).

So far, we have talked about 'humans' rather than the one specific type of human (ourselves – *Homo sapiens*) that now inhabits the planet. There were other humans before us and, before them, what we might call 'pre-humans'. However, all humans belong to the **genus** *Homo*.

Figure 4.29 shows a timeline for the major **hominin** and **hominid** species based on the currently available fossil evidence. Looking carefully at Figure 4.30, you begin to see the evolution of humans. Fossils of many of the species along the early part of the timeline were found in Ethiopia. The country is therefore, the 'cradle of mankind'.

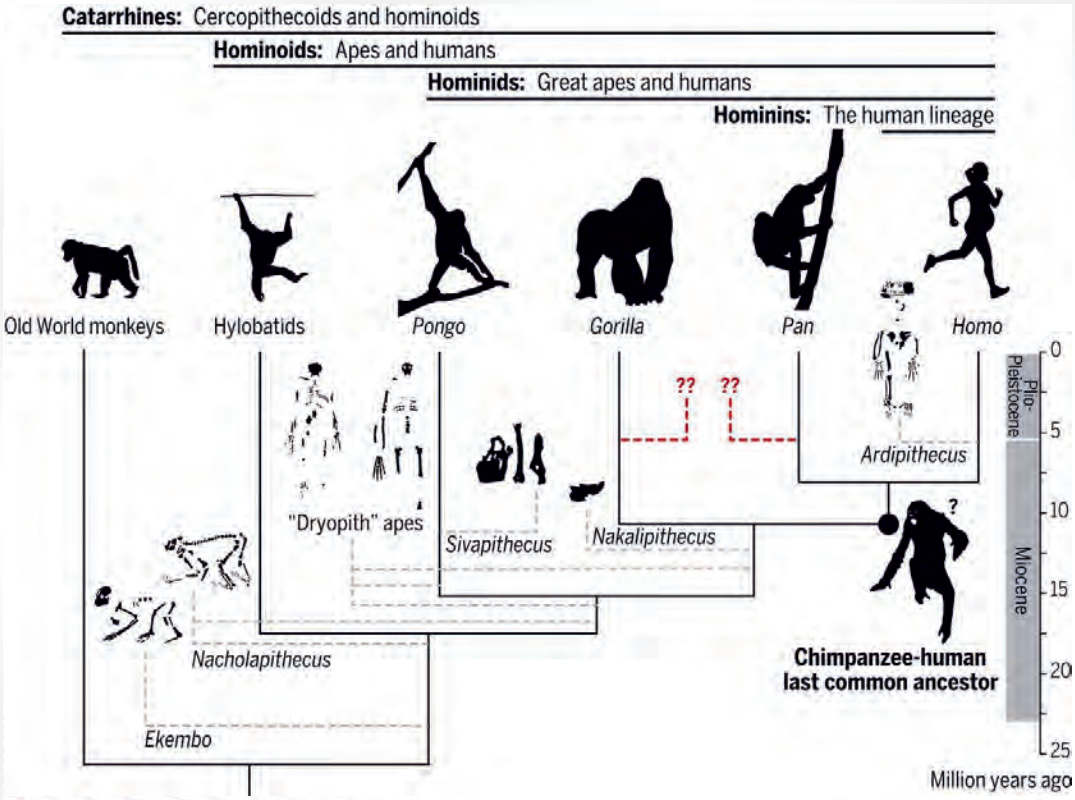


Figure 4.29 A timeline for the major hominin and hominid species

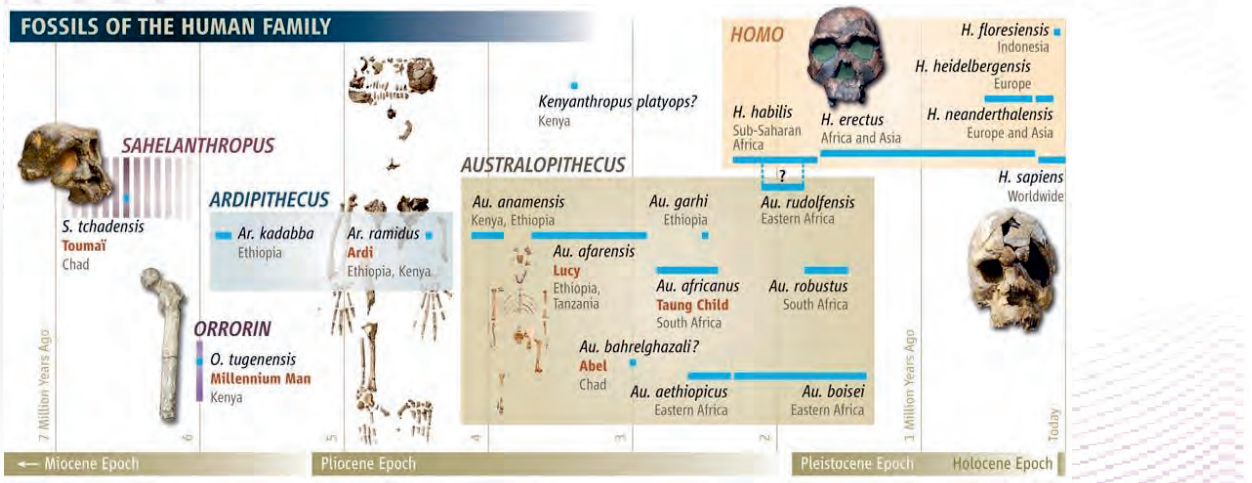


Figure 4.30 A timeline for the fossils of human family.

Lucy and Ardy

Both Lucy and Ardy are important fossils in explaining the evolution of modern humans and chimpanzees from a common ancestor. Lucy was discovered by Donald Johanson and Tom Gray in 1974 at Hadar, Ethiopia. Lucy is a fossil dated at about 3.2 million years. She was an adult female of about 25 years and belonged to the species *Australopithecus afarensis*. Her skeleton was about 40% complete, an unusually high proportion for a fossil skeleton. Her pelvis, femur (the upper leg bone) and tibia show that she was bipedal (could walk upright on two legs) (Figure 4.31).

However, there is also evidence that Lucy was partly arboreal (tree-dwelling). She was about 107 cm (42″) tall and about 28 kg (62 lbs) in weight. At the time she was discovered, Lucy represented one of the oldest fossil hominins. The proportions of her humerus and femur were mid-way between those of modern humans and chimpanzees.

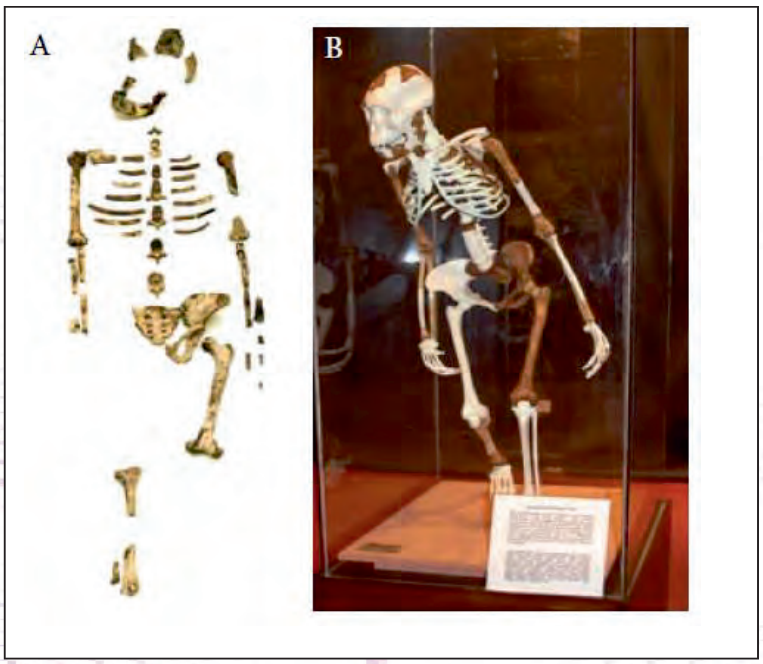


Figure 4.31 A – The original Lucy fossil; B – The Lucy display including reconstructed parts

Lucy had a brain about the same size as that of a chimpanzee, so her discovery was able to settle a debate amongst biologists at the time– which came first, large brain or bipedalism? Clearly bipedalism came before big brains.

The Ardi fossil (together with many other similar fossils) was first discovered in 1992, in the Afar dessert in Ethiopia, but it was only in 2009 after many years' analysis, that

research papers were finally published that gave Ardi a unique position in the human evolution.

Ardi was 1.2 million years older than Lucy, was also female who belonged to the species *Ardipithecus ramidus*. One significant feature about Ardi was that she was also bipedal. At 4.4 million years old, Ardi is the nearest fossil to the 'common ancestor' of humans and chimpanzees that has so far been found. This finding finally proved that the common ancestor of humans and chimpanzees could not have resembled a chimpanzee, as chimpanzees are not truly bipedal. However, there was signs of being adapted for both bipedal walking and arboreal life (Figure 4.32).

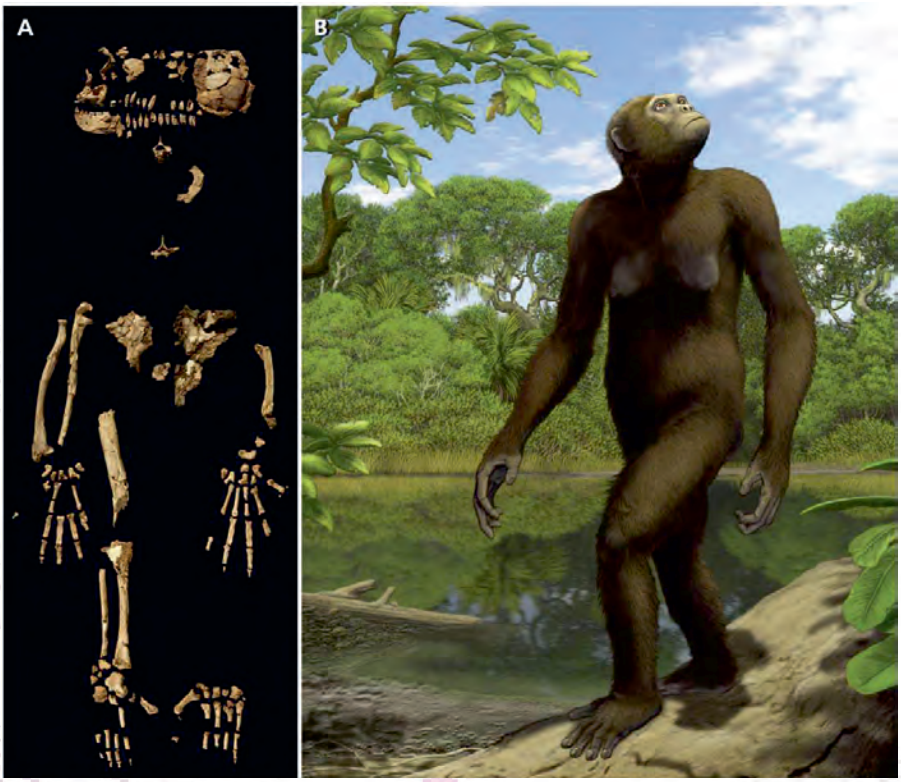


Figure 4.32 A relatively complete skeleton of *Ardipithecus*, which lived 4.4 million years ago. B: *Ardipithecus* shows signs of being adapted for both bipedal walking and arboreal life

How brain size changed during human evolution?

During the course of human evolution, the brain has got bigger. Studies on comparative anatomy of fossils revealed that the cranial capacity has increased with each new hominid species evolved (Figure 4.33). However, the brain has increased in size as a proportion of body mass. Species of *Australopithecus* have a brain that is between 0.7% and 1.0% of their body mass, whereas modern humans have a brain size between 1.8% and 2.3% of their body mass. The brain of *Homo sapiens* uses 25% of the resting energy requirement, compared with 8% in the great apes.

A larger brain allows humans to:

- run faster and in a more upright posture
- plan in advance to avoid attack
- develop and use tools and weapons

Activity 4.25

Read about emergence of *Homo sapiens* and present to the class.

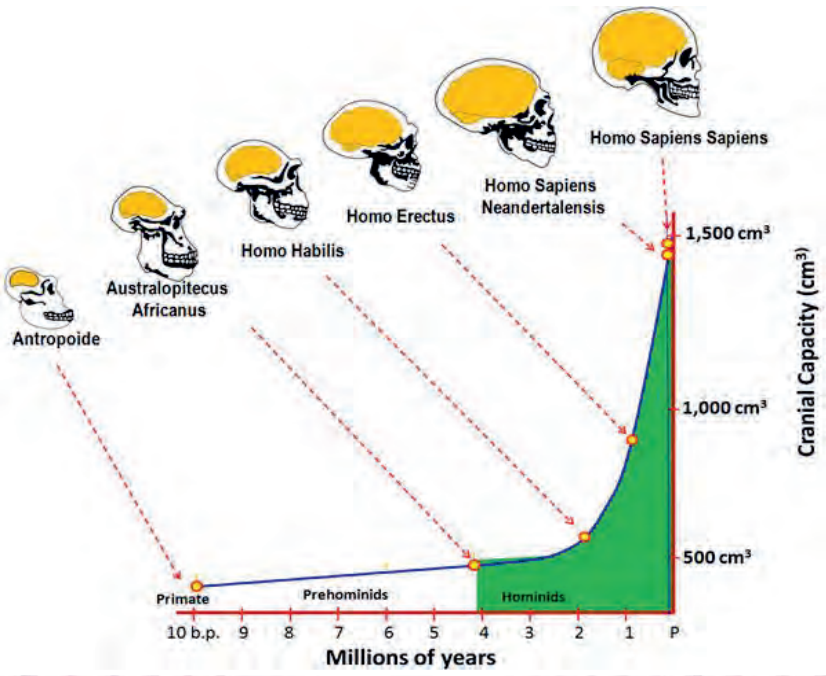


Figure 4.33 Brain size in different hominids

These abilities clearly depend on other physical adaptations such as longer legs, more nimble fingers and a straighter spine, but, without the larger brain to co-ordinate the activities; the physical changes would not confer the same advantage.

Are we still evolving?

Homo sapiens (modern humans) first appeared in Africa and have since migrated to all other parts of the world. Figure 4.34 shows these migratory patterns together with the time (thousands of years ago) when they took place.

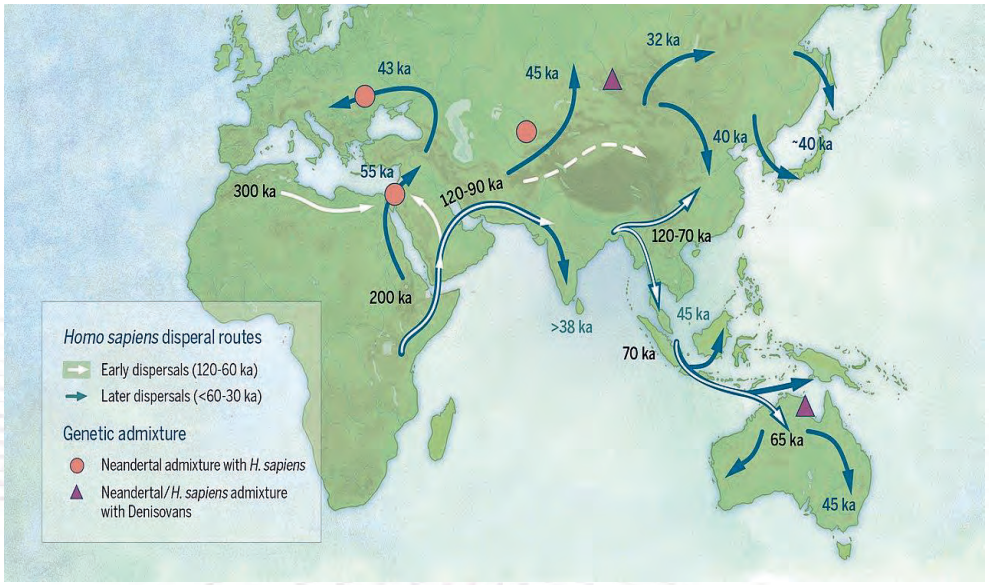


Figure 4.34 The migration of modern humans out of Africa – it all begins in East Africa. Numbers indicate the time (in years) since each stage of the migration.

As humans moved from Africa into different areas of the world, they encountered different environments. Different selection pressures in the different environments resulted in the different human populations evolving along different lines.

For example, as humans encountered colder climates, body features that gave a survival advantage to conserve heat were selected for. These included:

- a shorter, squatter body shape; this reduces the surface-area-to-volume ratio and so reduces the rate of heat loss by radiation
- an increased layer of adipose tissue under the skin to act as insulator.

- increased hairiness; this reduces heat loss by convection

Humans have been evolving into different 'races' for thousands of years. The classification of these races is difficult and there is some disagreement about their exact nature.

Activity 4.26

Search from books and other sources about different types of human races and the disagreement on the classification of the races. Report your finding to the class.

Activity 4.27

Ethiopia plays a central role in the story of human evolution. Using this text book, other books and internet, read as much as you can on the discovery and importance of Lucy, Ardi and Selam in the story of human evolution. Reflect your findings to the class.

4.1.6. Mutation

By the end of this section, the learner will be able to:

- Define mutation
- Examine the different types of mutations with examples
- Describe the causes of mutation
- Appreciate the effects of mutations on living things

Keyword

Mutation is a random change in genetic information

A **mutation** can be caused by several factors but is divided into two parts. If the agent that caused the mutation cannot be identified then it is known as a **spontaneous mutation**. If the mutation can be identified then it is called an **induced mutation**. Substances that cause mutations are radiation, x-ray, ultra-violet radiation, nuclear radiation and certain chemical substances. These agents can also be called **mutagenic agents** or **mutagens**. There can be large

structural changes involving the whole chromosomes or parts of chromosomes, or changes that involve only a single base. The changes involving only a single base are called **point mutations**.

Point mutation

There are several types of point mutation, in which one of the bases in the DNA sequence of a gene is altered, usually by being copied wrongly when the DNA replicates. The different point mutations are:

- substitution
- addition
- deletions

Activity 4.28

Make a small group and use the internet, books, and other relevant sources to discuss and describe the causes and effects of mutation on living things. Reflect your findings to the class.

These mutations occur quite randomly when the DNA is replicating and each involves a change to just one base, but the change to the gene can be dramatic and the result can be that the protein the gene should code for is not made at all or a different protein is made (Figure 4.35)

A point mutation is a change in a single nucleotide in DNA. This type of mutation is usually less serious than a chromosomal alteration. An example of a point mutation is a mutation that changes the codon UUU to the codon UCU.

Table 4.2 Description of point mutation

Type	Description	Example	Effect
Silent	mutated codon codes for the same amino acid	CAA (glutamine) → CAG (glutamine)	none
Missense	mutated codon codes for a different amino acid	CAA (glutamine) → CCA (proline)	variable
Nonsense	mutated codon is a premature stop codon	CAA (glutamine) → UAA (stop) usually	serious

Substitution

Guanine replaces thymine in this substitution. The triplet ATT has been changed to ATG (no other triplet is affected). The original triplet, ATT, codes for the amino acid isoleucine.

However, the new triplet, ATG, codes for methionine (see Figure 4.35). As a result, a different protein will be synthesised, which may or may not be significantly different from the original. One different amino acid in a protein does not always make a functional change.

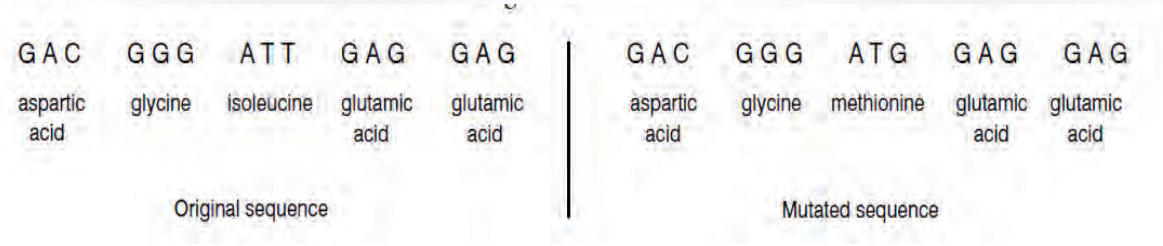


Figure 4.35 A substitution mutation

If a substitution of just one base in the sixth triplet of the gene coding for one of the four polypeptides in the haemoglobin molecule alters the triplet from GAG to GTG.

This results in the amino acid valine replacing glutamate in the polypeptide chain. The different haemoglobin molecule formed results in the condition known as **sickle-cell anaemia** (Figure 4.36)**.**

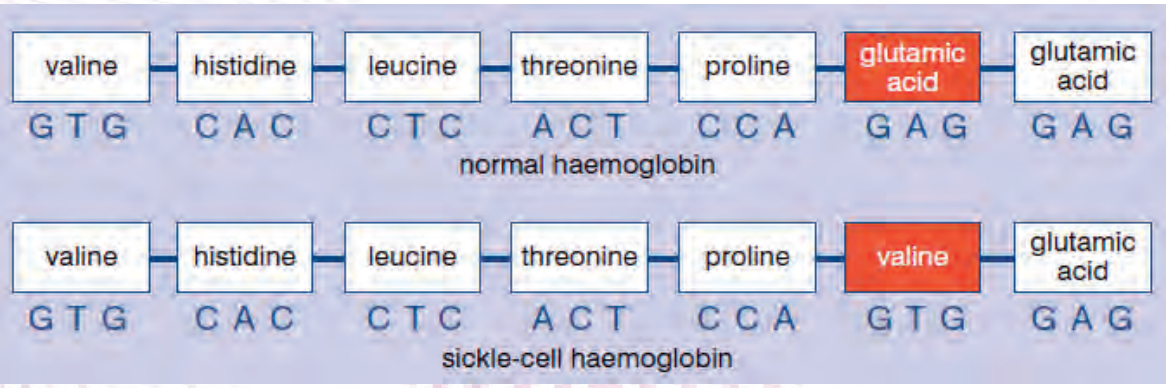


Figure 4.36 Sickle-cell anaemia

Addition and deletion

In a **deletion mutation,** a base is 'missed out' during replication, whereas in additions, an extra base is added **(Figure 4.37).** Both deletion and additions are more significant mutations than substitutions. The reason for this is that they do not just alter the triplet in which the mutation occurs. Because there is one fewer or one extra base, the whole sequence after the

Keyword

Deletion mutation a mutation caused by one DNA nucleotide being omitted from the sequence.

point of the mutation is altered. We say that there has been a frameshift and these are frameshift mutations. A totally different mRNA is produced (if one is produced at all) and a non-functional protein or no protein at all. Sometimes, a whole triplet is missed out or inserted. This will result in either one extra or one fewer codon in the mRNA. In turn, this will lead to one extra or one fewer amino acid in the polypeptide chain.

Another way of thinking about frameshifts

Look of this sequence of letters: THEMANWASHOTANDRANF ORHISHAT

If we give this a 'reading frame' of three letters, it becomes:

THE MAN WAS HOT AND RAN FOR HIS HAT

and it makes sense. But if we take out the S at the end of WAS (a deletion mutation), it becomes:

THE MAN WAH OTA NDR ANF ORH ISH AT

In other words it no longer makes sense. In genetic terms it is **missense** mutation.

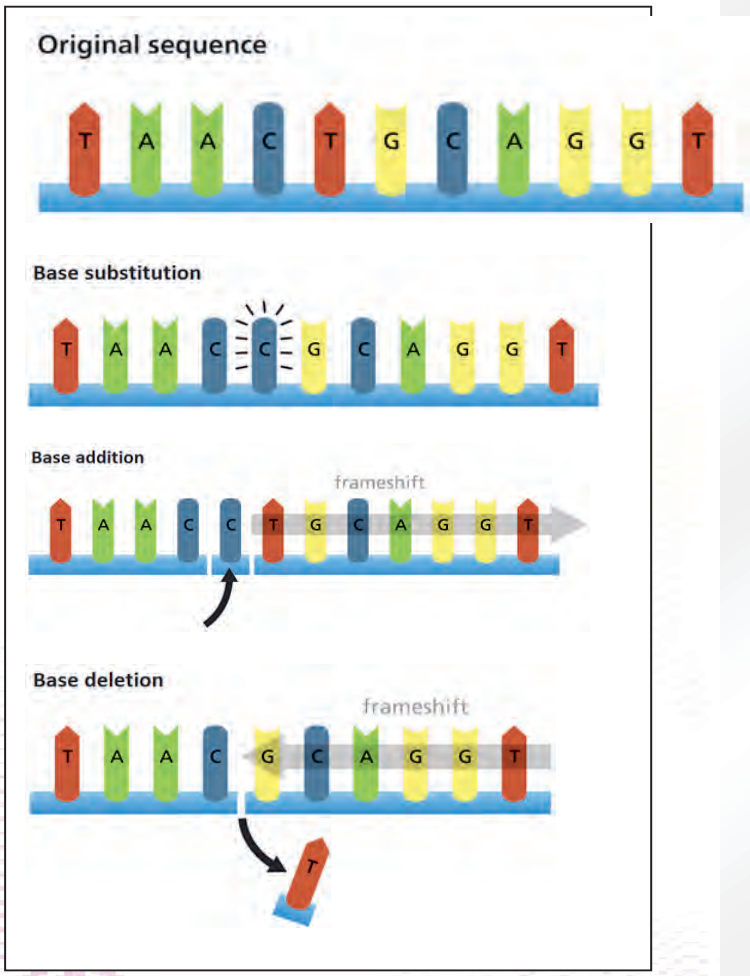


Figure 4.37 Types of point mutation

What causes point mutations and what are the consequences of gene mutations?

Activity 4.29

Search different types of sources and prepare a report to the class the following points

a. Possible causes of mutation.

b. Consequences of gene mutations

Chromosomal mutation

A **chromosomal mutation** is a mutation involving a long segment of DNA. Chromosomal mutation occurs when there is any change in the arrangement or structure of the chromosomes. Chromosomal mutation occur most often during meiosis at crossing over in prophase I. There are several different mutation types that result in a change in the structure of a chromosome such as duplication, deletion, inversion and translocation (Figure 4.38). They are much bigger events than point mutations and usually result in the death of a cell. They may also affect the whole organism. For example, if essential parts of the DNA are affected by chromosomal mutations, a foetus may be aborted. There are different types of chromosome mutations.

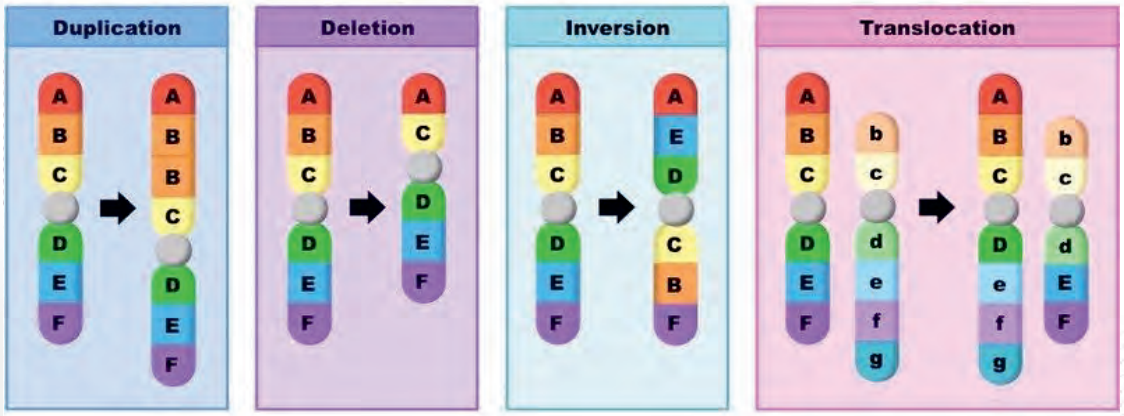


Figure 4.38. Types of Chromosomal mutations

Types of Chromosomal Mutations

Most chromosomal mutations are either Chromosomal Mutations I or Chromosomal mutations II.

- Chromosomal Mutations I involve the processes of inversion, deletion, duplication/amplification or translocation

- Chromosomal Mutations II involves aneuploidy and polyploidy.

A. Chromosomal mutations I

Chromosomal mutations I mutations alter the structure of the chromosome since they tend to break and these pieces often form sticky ends.

Inversion

Inversion chromosomal mutation is a kind of chromosomal mutations I and its segments are reversed from end to end. A piece of the chromosome is removed then reattached but in the opposite direction than it was originally. When this does not include the center or the centromere of the chromosome, it is called **paracentric inversion**. When the inversion does include the centromere, it is **pericentric**.

Deletion

Also known as partial monosomies, these occur when a piece of a chromosome accidentally gets removed or deleted. There can be cases with one piece deleted at the end (terminal deletion), two deletions – one deleted within the chromosome, and one on the end – (interstitial deletion). Microdeletions also occur when the deletions in the chromosomes are too small to be detected.

Duplication/Amplifications

As the name implies, an extra copy of a segment or the entire chromosome is present in the nucleus. These are also known as partial trisomies. Often an organism that usually has two copies of a chromosome will have three in the case of duplication. This can happen anywhere along the chromosome whether in the middle or on the ends.

Translocation

Translocation chromosomal mutation follows the route of biological translocation. This happens when a segment of a chromosome breaks off and then relocates to a completely different chromosome. This creates fusion chromosomes as one type of chromosome fuses with another.

Reciprocal translocation occurs when pieces of chromosomes "swap" places. **Robertsonian translocation** occurs when a segment of a chromosome is attached to another chromosome, causing an elongation of it. These can be balanced or unbalanced, where the chromosome is fully functional with no missing genetic information (balanced) or with important missing pieces and cannot function as normal (unbalanced). The translocation of chromosome 21 onto the 14th chromosome

causes the common genetic mutation of **down syndrome**.

B. Chromosomal Mutations II

The other type of chromosomal mutation categories Chromosomal mutations II than consists of aneuploidy and polyploidy. The general category of these is called heteroploidy since they cause a mutation by changing the number of chromosomes present in the cell.

Aneuploidy

This mutation either causes the loss or addition of a chromosome by the contortion of the chromosome
set. **Nondisjunction** during meiosis or mitosis usually results in this mutation.

Polyploidy

This mutation causes the creation of two sets of genomes within an organism. It is not usually common naturally however, it can be observed in some plants. It usually causes effects like giantism and the reduction of fertility.

3. The Advantages of Chromosomal Mutations

In some cases, chromosomal mutations can benefit the organism. Some mutations can help the organisms to survive better than others. Lactose tolerance became an advantage to have over others when numerous populations depended on cows and goats as sources of food. On the other hand, chromosomal mutations can be dangerous and even detrimental to the life of living organisms. Some of these can cause numerous problems within animals, plants, and humans.

Genetic Disorder

These are specific disorders or disabilities caused by mutations within the organism's DNA. These can be small genetic issues that may barely affect the individual or larger issues that may bring major concerns to the individual. A chromosomal disorders list can be seen below:

- Trisomy 21: Down Syndrome
- Trisomy 18
- Trisomy 13
- Klinefelter Syndrome
- XYY Syndrome
- Turner Syndrome
- Triple X Syndrome

 Activity 4.30

Search from different books and internet about different types of chromosome mutations (inversion, deletion, insertion, duplication etc). Report your finding to the class.

4.1.7. Genetic Drift

 By the end of this section, the learner will be able to:

Discuss Genetic drift.

What is genetic drift?

 Keyword

Genetic drift is a mechanism of evolution in which allele frequencies of a population change over generations due to chance events. Genetic drift is change due to "sampling error" in selecting the alleles for the next generation from the gene pool of the current generation.

Allele frequencies can change due to chance alone. This is called genetic drift. Drift is a binomial sampling error of the gene pool. What this means is, the alleles that form the next generation's gene pool are a sample of the alleles from the current generation. When sampled from a population, the frequency of alleles differs slightly due to chance alone.

Alleles can increase or decrease in frequency due to drift. The average expected change in allele frequency is zero, since increasing or decreasing in frequency is equally probable. A small percentage of alleles may continually change frequency in a single direction for several generations just as flipping a fair coin may, on occasion, result in a string of heads or tails. A very few new mutant alleles can drift to fixation in this manner.

The variance in the rate of change of allele frequencies is greater in small populations than in large populations. Let's make the idea of drift more concrete by looking at an example. As shown in Figure 4.39, we have a very small rabbit population that's made up of 8 brown individuals (genotype BB or Bb) and 2 white individuals (genotype *bb*). Initially, the frequencies of the *B* and *b* alleles are equal. What if, purely by chance, only the 5 circled individuals in the rabbit population reproduce? (Maybe the other rabbits died for reasons unrelated to their coat color, e.g., they happened to get caught in a hunter's snares.) In the surviving group, the frequency of the *B* allele is 0.7 and the frequency of the *b* allele is 0.3.

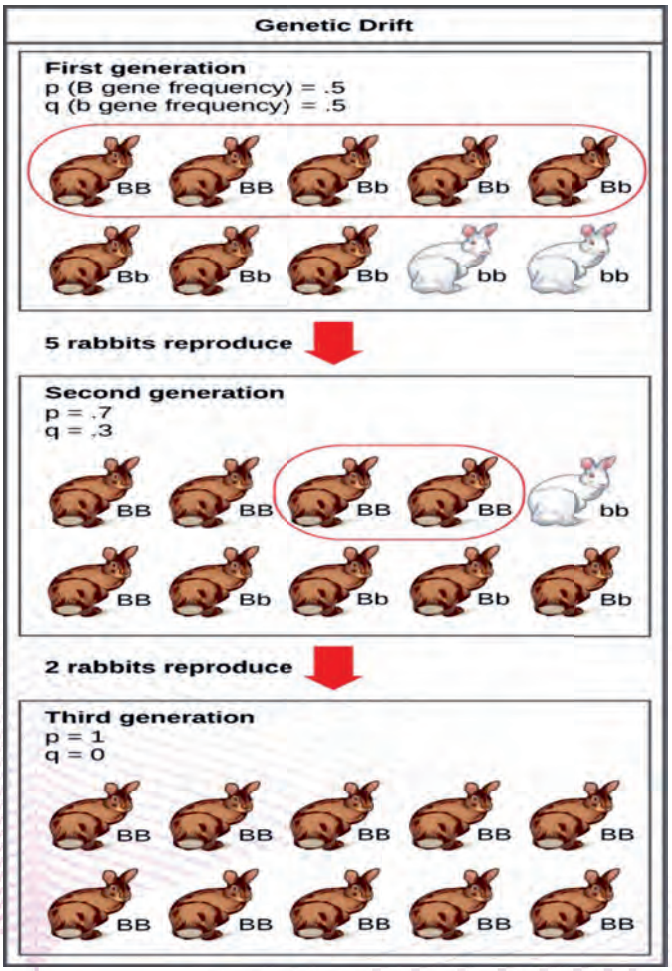


Figure 4.39 Example of genetic drift in a rabbit population

The allele frequencies of the five lucky rabbits are perfectly represented in the second generation. Because the 5-rabbit "sample" in the previous generation had different allele frequencies than the population as a whole, the frequencies of *B* and *b* in the population have shifted to 0.7 and 0.3 respectively. From this second generation, what if only two of the *BB* offspring survive and reproduce to yield the third generation? In this series of events, by the third generation, the *b* allele is completely lost from the population.

However, the overall rate of genetic drift (measured in substitutions per generation) is independent of population size. If the mutation rate is constant, large and small populations lose alleles to drift at the same rate. This is because large populations will have more alleles in the gene pool, but they will lose them more slowly. Smaller

populations will have fewer alleles, but these will quickly cycle through. This assumes that mutation is constantly adding new alleles to the gene pool and selection is not operating on any of these alleles.

Hardy–Weinberg Equilibrium

At Hardy–Weinberg Equilibrium, Allele Frequencies Do Not Change

The study of population genetics relies on the intimate relationship between allele frequencies and genotype frequencies. Each genotype's frequency is the number of individuals with that genotype, divided by the total size of the population. For example, if 64 of the 100 individuals in a population are homozygous recessive, then the frequency of that genotype is 64/100, or 0.64.

Hardy–Weinberg equilibrium is the highly unlikely situation in which allele frequencies and genotype frequencies do not change from one generation to the next. It occurs only in populations that meet the following assumptions:

(1) Natural selection does not occur;

(2) Mutations do not occur, so no new alleles arise;

(3) The population is infinitely large, or at least large enough to eliminate random changes in allele frequencies;

(4) Individuals mate at random; and

(5) Individuals do not migrate into or out of the population.

Hardy–Weinberg equilibrium is named after mathematician

Godfrey H. Hardy and physician Wilhelm Weinberg. They independently developed two simple equations that represent the relationship between allele frequencies and genotype frequencies. To understand their logic, begin by assuming that a gene has only two possible alleles, with frequencies p and q.

The first equation represents the frequencies of both alleles in the population:

$$p + q = 1$$

The two frequencies add up to 1 because the two alleles represent all the possibilities in the population. For example, the frequency of the dark fur allele (D) is 0.6; the frequency of the alternative allele d, which confers tan fur, is 0.4. (Tally the D and d alleles in the picture of the ferrets to verify these numbers.)

At Hardy–Weinberg equilibrium, we can use allele frequencies to calculate genotype

frequencies, according to the second equation in figure 12.12

p2 + 2pq + q2 = 1

In this equation, the proportion of the population with genotype DD equals p2 (0.36 for our ferrets) and the proportion with genotype dd equals q2 (0.16). To calculate the frequency of the heterozygous class, multiply pq by 2 (0.48). Since the homozygotes and the heterozygotes account for all possible genotypes, the sum of their frequencies must add up to 1.

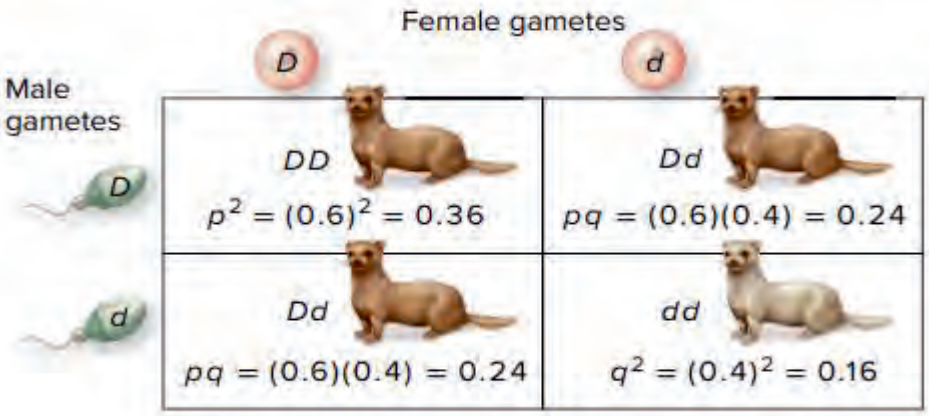
Allele frequencies: $p + q = 1$

Definition/equation	Example
p = frequency of dominant allele	p = frequency of *D* (dark fur) = 0.6
q = frequency of recessive allele	q = frequency of *d* (tan fur) = 0.4
$p + q = 1$	0.6 + 0.4 = 1

Genotype frequencies: $p^2 + 2pq + q^2 = 1$

Definition/equation	Example
p^2 = frequency of *DD* genotype	0.6 x 0.6 = 0.36
$2pq$ = frequency of *Dd* genotype	2 x 0.6 x 0.4 = 0.48
q^2 = frequency of *dd* genotype	0.4 x 0.4 = 0.16
$p^2 + 2pq + q^2 = 1$	$(0.6)^2 + (2 \times 0.6 \times 0.4) + (0.4)^2 = 1$

Reproduction (random mating)



Hardy–Weinberg Equilibrium. At Hardy–Weinberg equilibrium, allele frequencies remain constant from one generation to the next; evolution does not occur."

Table 4.3 Conditions for Hardy-Weinberg Equilibrium

Condition	Consequence if Condition Does Not Hold
1. No mutations	The gene pool is modified if mutations occur or if entire genes are deleted or duplicated.
2. Random mating	If individuals mate within a subset of the population, such as near neighbors or close relatives (inbreeding), random mixing of gametes does not occur and genotype frequencies change.
3. No natural selection	Allele frequencies change when individuals with different genotypes show consistent differences in their survival or reproductive success.
4. Extremely large population size	In small populations, allele frequencies fluctuate by chance over time (a process called genetic drift).
5. No gene flow	By moving alleles into or out of populations, gene flow can alter allele frequencies.

The genetic bottleneck effect

The **bottleneck effect** is an extreme example of genetic drift that happens when the size of a population is severely reduced. Events like natural disasters (earthquakes, floods, fires) can decimate a population, killing most individuals and leaving behind a small, random assortment of survivors.

The allele frequencies prior to the natural disasters may be very different from those of the population after the event, and some alleles may be missing entirely. The smaller population will also be more susceptible to the effects of genetic drift for generations (until its numbers return to normal), potentially causing even more alleles to be lost.

Imagine a bottle filled with marbles, which, represent individuals in a population. If a bottleneck event occurs, a small, random assortment of individuals survive the event and pass through the bottleneck (and into the cup), while the vast majority of the population is killed off (remains in the bottle). The genetic composition of the random survivors (Figure 4.40) is now the genetic composition of the entire population. A population bottleneck yields a limited and random assortment of individuals. This small population will now be under the influence of genetic drift for several generations.

Activity 4. 31

Discuss the following question in small group and reflect your opinion to the class.

How can a bottleneck event reduce genetic diversity?

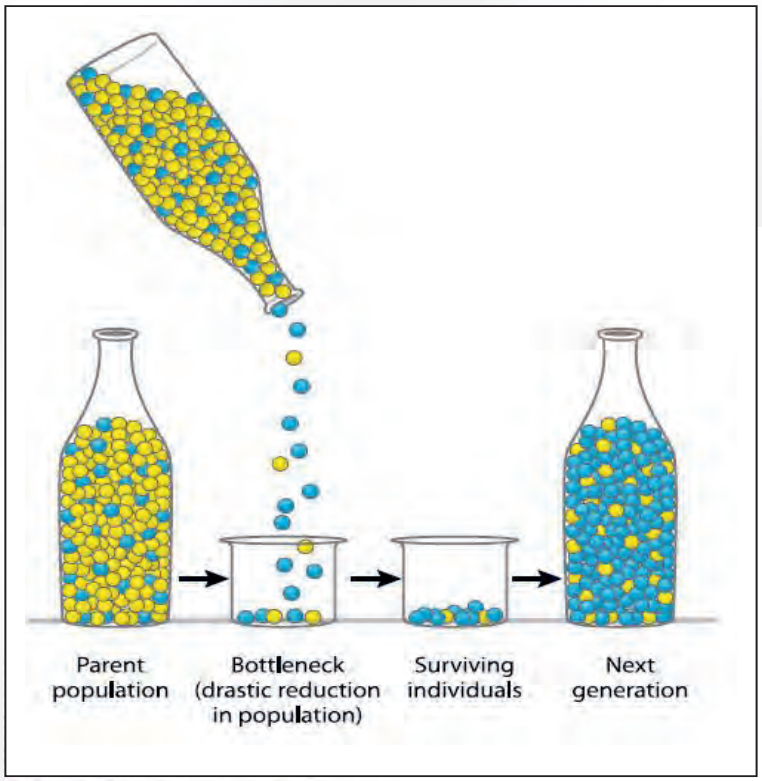


Figure 4.40. Bottleneck effect eliminates genes from a population

The founder effect

The **founder effect** is another extreme example of genetic drift that occurs when a small group of individuals breaks off from a larger population to establish a colony (Figure 4.41).The new colony is isolated from the original population, and the founding individuals may not represent the full genetic diversity of the original population. That is, alleles in the founding population may be present at different frequencies than in the original population, and some alleles may be missing altogether. The small size of the new colonies means that they will experience strong genetic drift for generations. The founder effect is similar in concept to the bottleneck effect, but it occurs via a different mechanism (colonization rather than catastrophe).

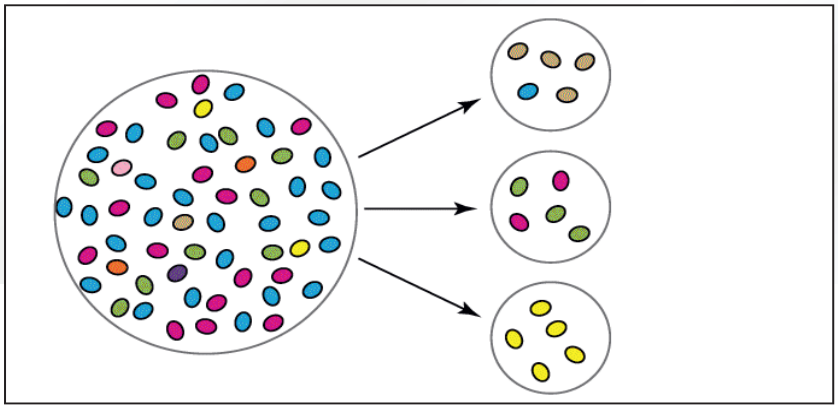


Figure 4.41 Founder effect eliminates genes from a population

Activity 4.32

Search from different sources (books, internet) about Ellis-Van Creveld syndrome (whose symptoms include polydactyly, or extra fingers, and other physical abnormalities). With the information you have about genetic drift and write a report of your findings.

4.1.8. Gene flow (immigration and emigration)

By the end of this section, the learner will be able to:

- Discuss Gene flow
- Describe the roles of immigration and emigration on gene flow and speciation.

Gene flow also called migration- is any movement of individuals, and/or the genetic material they carry from one population to another. Gene flow includes lots of different kinds of events, such as pollen being blown to a new destination or people moving to new cities or countries. If gene versions are carried to a population where those gene versions previously did not exist, gene flow can be a very important source of genetic variation. In Figure 4.42 below, the gene ersion for brown coloration moves from one population to another.

Keywords

Gene flow *is* any movement of individuals, and/or the genetic material they carry, from one population to another

Migration: The permanent movement of genes into or out of a population, causing a change in allele frequency

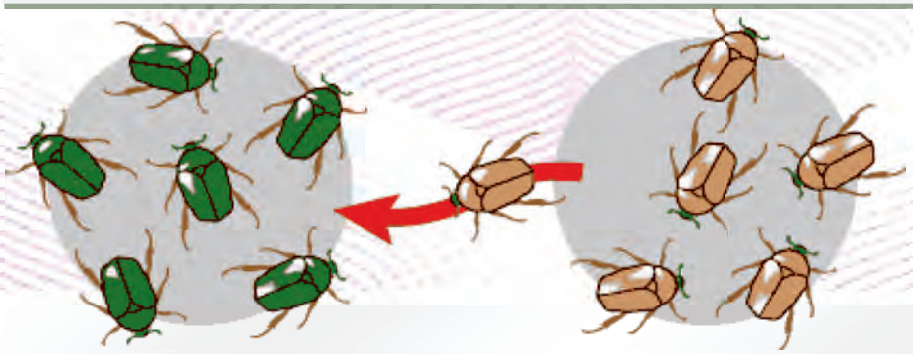


Figure 4.42 Gene flow (immigration)

Immigration is when new organisms join a population, changing allele frequencies. Emigration is when members of a population leave, taking with them their genes. These phenomena change the overall balance of the gene pool of the populations. Gene transfer is the flow of alleles from one species to another. Horizontal gene transfer is especially common in bacteria.

4.1.9. Causes of species extinction

By the end of this section, the learner will be able to:

- Explain causes of species extinction

Evidence suggests that anthropogenic effects and natural disaster played significant role for the direct and indirect causes of species extinction.

Activity 4.33

Form a small team and explore drivers of extinction like climate change, human activities, greenhouse gases, and natural disasters from various sources (books, internet etc). You are expected to seek solutions to mitigate habitat loss and prevent extinction. Prepare a report and discuss your findings to the class.

4.2. Renowned Anthropologists in Ethiopia

By the end of this section, the learner will be able to:

Appreciate the works of renowned anthropologists in Ethiopia.

Activity 4.34

Search from different sources (books, internet) about gene flow. Write a summary of your findings and present your findings to the class.

 Activity: 4.35

Your teacher may wish you to know the work of renowned Ethiopian anthropologists

4.3. Renowned Evolutionists in Ethiopia

 By the end of this section, the learner will be able to:

- Appreciate the works of renowned evolutionists in Ethiopia

 Activity: 4.36

Make a small group and explore from the internet and other sources about human evolution discoveries from Ethiopia. Also search for the work of Ethiopian scientists involved in the discovery of human evolution in Ethiopia. Prepare a report and

Unit summary

In this unit,

You have learnt about evolution which can be defined as the change in genetic composition of a population over successive generations. You have been introduced with the major theories that explain the origin of life on Earth, which include:

- Special creation theory: a 'supreme being' is believed to have created life or directs its creation and evolution.
- Spontaneous generation theory: life is believed to arise from non-living matter; this was finally disproved by the experiments of Francesco Redi and Louis Pasteur
- Eternity of life theory: life is believed to have existed forever and will continue to exist forever. Hence, no origin is required.
- Cosmozoan theory: either life forms or the organic molecules needed for the origin of life are believed to have been brought to Earth by meteorites and comets.
- Biochemical origin theory:life is believed to have originated as a result of biochemical reactions creating first the necessary organic molecules, which then

became assimilated into 'pre-cells', which eventually evolved into cells.

You also studied that Miller's 'spark discharge' experiment showed that the organic molecules essential for life could be synthesized on Earth 4.5 billion years ago. The oldest photo-autotrophs are the cyanobacteria and they were largely responsible for the increase in free oxygen in the atmosphere. In 1809, Lamarck proposed a two-part theory to explain evolution based on:

- use and disuse
- inheritance of acquired characteristics

- In 1859 Darwin proposed the theory of natural selection based on:

- a struggle for existence
- natural variation in the offspring

- Particularly, you have learnt about Darwin's theory of natural selection, which stated that 'those members of a species which are best adapted to their environment will survive and reproduce in greater numbers than others less well adapted'.

- Apart from theory of natural selection, a detailed account of concepts regarding have been provided. Based on this, it has been stated that Neo-Darwinism takes into account our knowledge of genetics, biochemistry and ethology to modify Darwin's original theory to include the effect of selection on allele frequency and frequency of behavior patterns.

- On a similar vein, other insights on the origin of life have been provided. Evidence supporting the theory of evolution comes from many areas, including:

- palaeontology (the fossil record)
- comparative anatomy
- comparative embryology
- comparative biochemistry

- Another important point you have studied in this unit was about the use of fossils to determine the origin of life. In this case, fossils can be dated using:

- Stratigraphy –analyzing the sequence and thickness of different layers (strata) of rocks
- radioactive carbon (C14) dating – measuring the ratio of radioactive carbon to normal carbon – is suitable for fossils up to 60 000 years old

This unit was also devoted to illustrating the following scientific concepts, facts and evidence related to evolution. These are:

- Homologous structures are evidence of a common origin and divergent evolution.
- Analogous structures are evidence of a different origin and convergent evolution.
- Similar patterns of embryological development in vertebrates suggest a common origin.
- The extent of differences in molecules common to many species (for example, DNA, cytochrome c, hemoglobin) is a measure of their relatedness.

A species can be defined as 'a group of similar organisms with a similar biochemistry, physiology and evolutionary history that can interbreed to produce fertile offspring.

The gene pool is the sum of all the alleles of all the genes in a population. The gene pool is constantly changing as a result of mutations introducing new genes into the population and disadvantageous alleles being lost through natural selection. In natural selection:

- individuals with an advantageous allele survive to reproduce in greater numbers
- the process repeats over many generations in which the frequency of the advantageous allele increases in each generation

In directional selection, one extreme of a range of values for a feature has a survival advantage; the range of values for the population shifts towards the extreme with the selective advantage. In stabilizing selection, the two extremes are at a selective disadvantage compared to those showing the mean values for a particular feature; the range is compressed around the mean. In disruptive selection, both extremes have a selective advantage compared with the mean; two distinct types begin to emerge showing the extreme values of the original population. If two populations of the same species are isolated for sufficient time, they may become so different genetically as to evolve into separate species. Speciation involving geographical separation is called allopatric speciation. Speciation involving separation within one area which is a result of different breeding strategies is called sympatric speciation; the different strategies can involve. Divergent evolution involves adaptive radiation and is the evolution of one basic 'type' into several different 'types' as a result of different selection pressures. Examples include

- the divergent evolution of the pentadactyl limb into flippers, legs, wings, etc.

- the divergent evolution of the beaks (and other features) of Darwin's finches on the Galapagos Islands

Convergent evolution is the evolution of similar 'types' with similar adaptations from several different original 'types'. Examples include:

- the elongated 'snouts' (and other features) of the different anteaters of the world
- the wings of birds, insects, pterodactyls, etc.

Modern humans and other primates have evolved from a common primate ancestor that lived before the dinosaurs became extinct. Modern humans and chimpanzees have evolved from a common ancestor that lived about 6 million years ago. Two distinctive features of modern humans are:

- large brains
- true bipedalism

The fossil Lucy was significant because it showed that bipedalism evolved before large brains. The fossil Ardi was significant because it showed that the common ancestor of humans and chimpanzees cannot have resembled a chimpanzee.

Unit review questions

Choose the best answer

1. Which of the following is *not* a part of Darwin's theory of natural selection?

   A. Individuals of a population vary

   B. Organisms tend to over-reproduce themselves

   C. There are limited resources for which individuals compete

   D. Modifications an organism acquires during its lifetime can be passed to its offspring

   E. Variations possessed by individuals of a population are heritable

Direction: Answer question number 2 based on the following diagram

2. Why did Pasteur bend the neck at curve

   a. To make the flask air tight

   b. To trap dust & microbes

   c. To enable the steam – easily comes out

   d. To make dust & microbes pan in & out

3. In the Miller and Urey's simulation experiment to study organic molecules formation in primeval atmosphere of the earth, all the following gases were used except which?

   A. Ammonia

   B. Nitrogen

   C. Methane

   D. Oxygen

   E. Hydrogen

4. If the amount of C-14 relative to C-12 in a sample is one-quarter of that in living organisms at present, what is the age of the fossil at 5,730 half-life years?

   A. 11,460 years

   B. 17,190 years

   C. 22,920 years

   D. 50,000 years

5. Which one of the following includes all the others?

   Natural selection

   Disruptive selection

   Directional selection

   Stabilizing selection

6. Birth mass in humans is an example of which of the following selections?

   A. Disruptive selection

   B. Directional selection

   C. Stabilizing selection

   D. Diversifying selection

7. When the human and other primate DNA compared, human's DNA are found distantly related to

   Rhesus monkey

   Chimpanzees

   House mouse

   Gibbon

8. The many species of Galapagos Finches are adapted to eat different foods. This is the result of

   A. Gene pool

   B. Genetic Drift

   C. Survival of the fittest

D. Adaptive radiation

9. A bell shaped curve in a variable indicates which kind selection?

A. Stabilizing selection C. Divergent selection

B. Unidirectional selection D. Disruptive selection

10. According to the theory of evolution proposed by Charles Darwin, which of the following is the most important driving force of evolution?

A. Over reproduction C. Mutation

B. Natural selection D. Variation

11. Theory of inheritance of acquired characters was given by

A. Wallace B. Darwin C. Lamarck D. Hugo De Vries E. Mendel

12. During which of the following periods did the extinction of dinosaurs happen?

A. Cambrian B. Ordovician C. Jurassic D. Cretaceous E. Permian

13. The Study of fossils is

A. Herpetology B. Serology C. Palaeontology D. Homology

14. Which of the following is the direct ancestor of Homo sapiens?

A. *Australopithecus* C. *Homo erectus*

B. H. sapiens Neanderthals D. Homo sapiens fossils

15. Species occurring in different geographical area are called as

A. Sympatric C. Sibling

B. Allopatric D. Neopatric.

16. Which of the following are homologous organs?

A. Wings of bird and hands of human

B. Wings of bird and wings of insect

C. Nails of human being and claws in animals

D. Wings of bat and wings of cockroach

17. Similarities in organism with different genotype indicates

A. Microevolution C. Convergent evolution

B. Macroevolution D. Divergent evolution

18. Which of the following is most important for speciation?

A. Seasonal isolation C. Behavioral isolation

B. Reproductive isolation D. Tropical isolation

19. Adaptive radiation refers to

A. Evolution of different species from a common ancestor

B. Migration of members of a species to different geographical areas

C. Power of adaptation in an individual to a variety of environments

D. Adaptations due to geographical isolation.

20. Which theory of the origin of life states that a supreme being Somehow involved in the creation of life

A. Eternity life C. Special creations

B. Cosmozoan theory D. Spontaneous generation

21. On which of the following evolutionary ideas do Lamarck & Darwin fully agree?

A. Acquired traits are inherited

B. Natural selection leads to evolution

C. Life is a result of natural processes

D. Evolution occurs by the use & disuse of body parts

22. The scientist who tested the biochemical hypothesis of the origin of life

A. Oparin B. Miller C. Pasture D. Fredi

Provide the correct answer for the following questions

1. List at least one point in favour and one point against the theories on the origin of life listed here under. You may have to imagine yourself as a 'person of the times' in some cases.

a. Special creation

b. Spontaneous generation

c. Eternity of life

d. Cosmozoan (panspermia)

e. Biochemical (abiogenesis)

2. (a) Explain what is meant by each of the following terms:

i. Evolution

ii. convergent evolution

iii. divergent evolution

(b) How does the fossil record provide evidence for evolution?

(c). Explain how neo-Darwinism has modified Darwin's original theory of natural selection.

3. (a) In each of the following examples of natural selection, identify:

- the selection pressure (feature of the environment that is selecting for some types and against others), and the type within the population that is best adapted.

i. wildebeest hunted by lions

ii. Bacteria in a hospital where penicillin is widely used

iii. Nettle plants with different-sized leaves in a shaded woodland area.

(b) Allopatric speciation and sympatric speciation are two processes by which new species can evolve. Explain:

- one similarity between the two processes

- one difference between the two processes

4. (a). Explain what is meant by the term 'species'.

(b) King cheetahs have a different pattern of spots from ordinary cheetahs. At first it was thought that they might be a different species. Suggest how:

i. the difference in spot pattern might have arisen

ii. biologists have been able to show that king cheetahs are members of the same species as other cheetahs

5. The amino acid sequences of one of the polypeptide chains of haemoglobin from nine animals were determined. The results are shown in the table.

Type of haemoglobin	Number of amino acids different from human haemoglobin
Human	0
Gorilla	1
Gibbon	2
Rhesus monkey	8
Horse	25
Chicken	45
Frog	67
Sea slug	127

(a) Use the information to draw a phylogenetic tree of the organisms.

(c) It is possible to use DNA hybridisation to suggest relationships between species. Explain why

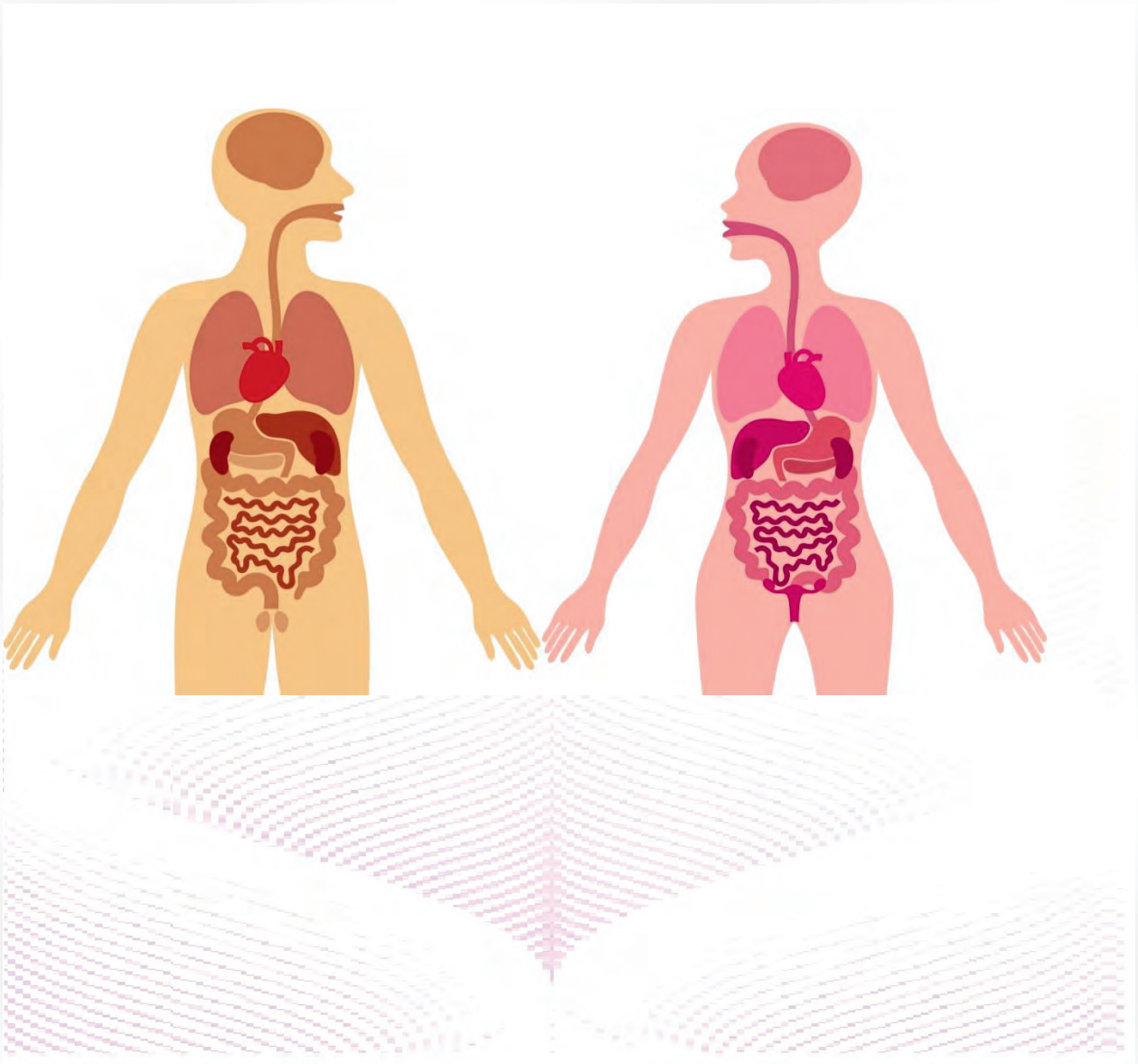
6. Explain the importance of each of the following in speciation:
   - Isolation of different populations
   - Mutation
   - Selection pressures
   - Reproductive isolation
7. Describe how the experiments of Redi and Pasteur were able to disprove the theory of spontaneous generation.
8. Describe (a) the Oparin/Haldane theory of abiogenesis (the biochemical origin of life).

(b) Three pieces of evidence that support this theory.

9. Write a short essay on human evolution. Include the following aspects of human evolution in the essay:

- The idea of a common ancestor with chimpanzees
- Some of the early humans that have existed
- The importance of bipedalism and large brain size
- The significance of the Lucy, Ardi and Selam fossils.

Unit 5: Human body system



After successful completion of this unit, the learner will be able to:

- Explain the structures and functions of the nervous system
- Explain how the organs of each organ system work together
- Explain what homeostasis is and how the human nervous and endocrine system helps maintain homeostasis
- Discuss how the nervous and endocrine system works
- Describe the effects of drug abuse on the normal functioning of the nervous and endocrine system

Self-questioning

Which parts your body systems get involved for coordination and rapid responses to the changes in the environment?

Body Coordination

There are two main forms of coordination in animals as a whole. These are nervous and hormonal coordination. Thus, the nervous system and the endocrine system are the two important systems that are responsible for body coordination. The nervous system uses nerve cells to pass electrical impulses along their length. They stimulate their target cells by secreting chemicals, known as neurotransmitters, directly on to them. On the other hand, the endocrine system produces chemicals (hormones) that are transported in the blood plasma to their target cells. The target cells have specific receptors on their cell-surface membranes and the change in the concentration of hormones stimulates them.

Table 5.1. Nervous system versus endocrine system

	Nervous system	Endocrine system
Speed of action	Seconds	Minutes to hours (even days)
Duration of action	Seconds to minutes	Minutes to days
Method of transmitting messages	Electrical	Chemical
Transport method	Neurones	Hormones

5.1. The Nervous System

After successful completion of this unit, the learner will be able to:

- Define nervous system.
- Describe the structure of nervous system.
- Describe the structure of neurons
- Explain the functions of different types of neurons
- Define reflex action
- Show the root of reflex arc with example
- Identify types of the nervous system
- Describe the mechanism of the conduction of nerve impules.
- Illustrate the effects of drug abuse on the nervous systems with local and international example

Activity 5.1

Make a small group and discuss on the following point and reflect your idea to the class

- Desecibe the differences and similarities of nervous system and endocrine system

The nervous system

Self-questioning

- What is nervous system?
- What are the constituents of central nervous system and peripheral

The **nervous system** is responsible for the reception and processing of sensory information from both the external and internal environments. The nervous system has two major divisions (Figure 5.1). The **central nervous system** (**CNS**) consists of the brain and spinal cord. The **peripheral nervous system** (**PNS**) consists of nerves outside the CNS.

The nervous system has three specifc functions:

1. The nervous system receives sensory input. Sensory receptors in skin and other organs respond to external and internal stimuli by generating nerve signals that travel by way of the PNS to the CNS.

2. The CNS performs information processing and integration, summing up the input it receives from all over the body.

3. The CNS generates motor output. Nerve signals from the CNS go by way of the PNS to the muscles, glands, and organs.

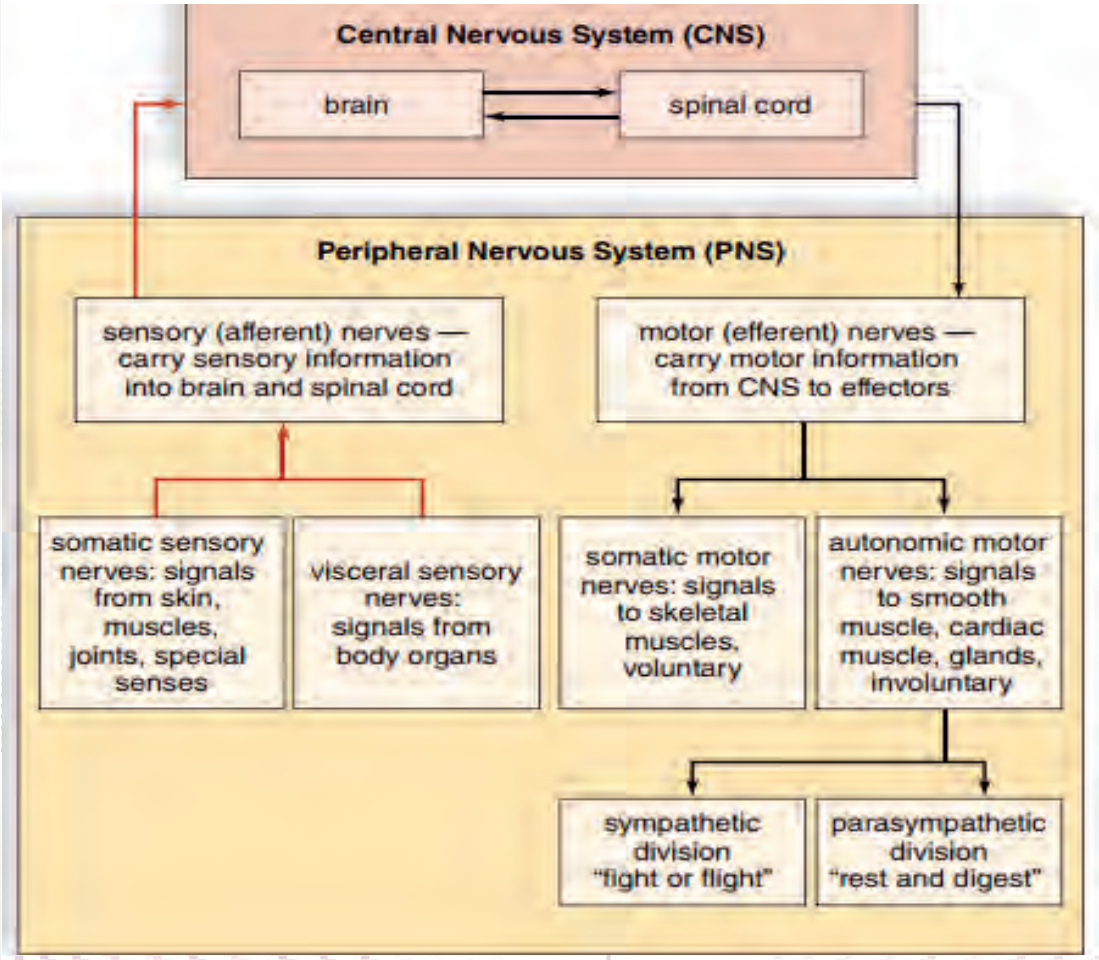


Figure 5.1 Nervous system with their brief functions

5.1.1. Neurons and their functions

 By the end of this section, the learner will be able to:

- Describe the structure of neurons.
- Mention the three types of neurons.
- Describe the function of neurons.

 Self-questioning

- What are the functional difference between neurons and glial cells?

The nervous system is composed of only two principal types of cells - neurons and supporting cells (glial cells). **Neurons** are the basic structural and functional units of the nervous system. They are specialized to respond to physical and chemical stimuli, conduct electrochemical impulses, and release chemical regulators. Through these activities, neurons enable the perception of sensory stimuli, learning, memory, and the control of muscles and glands.

Supporting cells aid the functions of neurons and are about five times more abundant than neurons. In the CNS, supporting cells are collectively called **neuroglia,** or simply **glial cells** (from the Middle Greek *glia* = glue). **Neuroglia** serve as supporting cells, providing support and nourishment to the neurons.

The basic unit of communication in the nervous system is the nerve cell (**neuron**). All neurons consist of : (1) a cell body, (2) dendrites, and (3) an axon (Figure 5.2). Dendrites and axons can be referred to generically as processes, or extensions from the cell body.

1). **Cell body:** The cell body contains the nucleus, as well as other organelles. Also known as a soma, the cell body is the neuron's core. The cell body consists of nucleus that carries genetic information, maintains the neuron's structure, and provides energy to drive activities. Most of the neurone cell bodies are located inside the central nervous system and form the grey matter. The Cell bodies that are located in the peripheral nervous system are called **ganglia.**

2). **Axon:** Each neurone has only one axon that conducts information away from the cell body. The axon will also branch at its terminal into many axon terminals. The axon delivers the impulse to another neurone or a gland or a muscle. Individual axons are termed nerve fibers, and collectively they form a **nerve.** Many axons are insulated with a fatty substance called **myelin sheath.**

3). **Dendrites:** Dendrites are short extensions that receive signals from sensory receptors or other neurons. Incoming signals from dendrites can result in nerve signals that are then conducted by an axon. Neurons can have more than one set of dendrites, known as dendritic trees. The number of dendritic tree neurons have generally depends on their role.

Myelin sheath: Myelin is a fatty substance whose purpose is to protect the neurone and to electrically insulate it, speeding up impulse transmission. The axons of peripheral nerves and long or large axons are covered by a myelin sheath. Within the peripheral nervous system Schwann cells wrapped in layers around the neurone form the myelin sheath. The gaps where there is no myelin sheath are called **nodes of Ranvier**. Some nerve fibres are unmyelinated, and this makes nerve impulse transmission significantly slower.

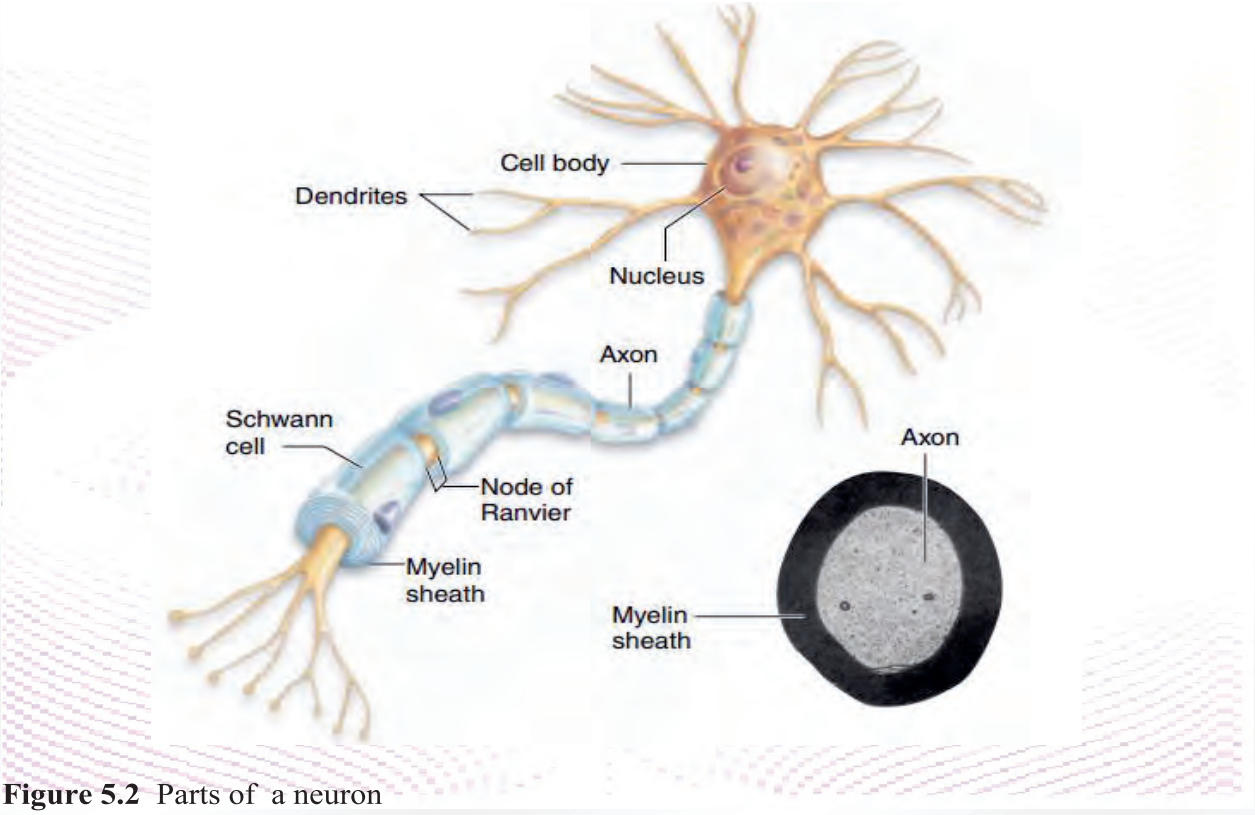


Figure 5.2 Parts of a neuron

Keywords

Dendrites: tree-like branches from nerve cell bodies that receive signals from other nerve cells at synapses

Axon: long process from nerve cell that carries the nerve impulse

Cellbody: the enlarged portion or rod granule that contains the nucleus.

Myelin sheath: fatty insulating sheath that grows around many nerves.

Node of Raniver: periodic gap in the insulating sheath (myelin) on the axon of certain neurons that serves to facilitate the rapid conduction of nerve impulses

Activity 5.2

Make a small group and discuss on the following point and reflect your idea to the class

- What is the difference between a neuron and a nerve?
- Do you think neurons are continuous like a 'wire'?

Types of neurons

Neurons vary in structure and function. In terms of function, scientists classify neurons into three broad types: **sensory**, **motor**, and **interneurons**.

1. **Sensory (affector/ afferent) neurons:** Sensory neurons carry messages from sensory receptors to the central nervous system. They have typically a long dendrite and short axon. Sensory neurons are triggered by the physical and chemical inputs from environment (stimuli) such as sound, touch, heat, and light.

2. Motor (effector/ efferent) neurons: Motor neurons transmit messages from the central nervous system to the effectors (muscles or glands). Motor neurons have a long axon and short dendrites. Motor neurons play a role in voluntary and involuntary movements. These neurons allow the brain and the spinal cord to communicate with muscles, organs, and glands all over the body.

3. Interneurons (association neurons): Interneurons are found entirely within the central nervous system. They pass signals

from sensory to motor neurons, or to integrate these functions.

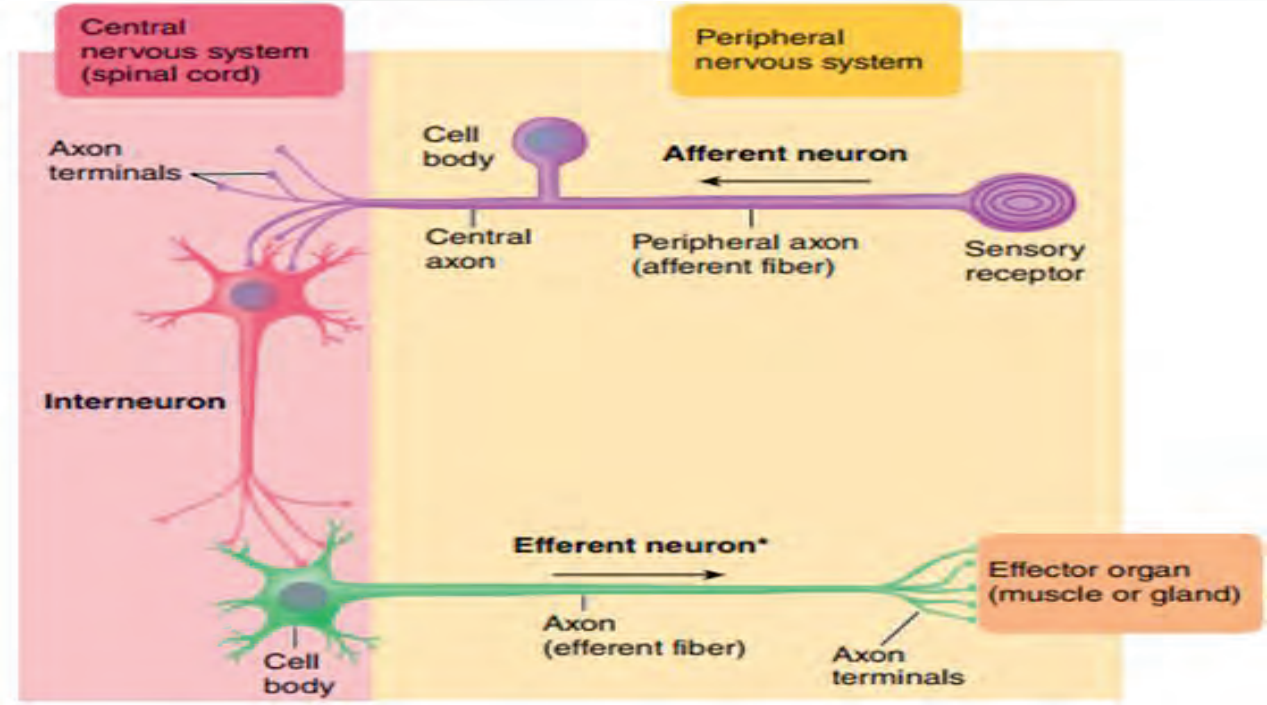


Figure 5.3 Types of neurones

The nervous system takes in information from our receptors. Once a stimulus is picked up by a receptor, the information is passed along special nerve cells, affector or afferent (sensory) neurons, to the central nervous system (CNS). In the CNS interneurons (associated neurons) pass signals from sensory neurons to motor neurons and other interneurons. Once the information has been processed in the CNS, instructions are sent out to the body along motot neurons called effector or efferent (motor) neurons. The summary of information flows through the nervous system in the following sequence:

Keywords

Affector (afferent) neuron that sends impulses from organs to the spinal cord and brain

Effector (efferent) neuron that sends impulses from the brain and spinal cord to organs

Interneurons form connections between afferent and efferent neurons

Stimulus → Reception by sensory receptor → transmission by afferent neuron →

integration by interneurons in CNS ⟶ transmission by efferent neuron

→ action by effectors

Nerves and nerve tracts

Activity 5.3

Make a small group and discuss on the following point and reflect your idea to the class

- Distinguish between Stimulus and response
- How sensory neurons, interneurons and motor neurons work.
- How CNS interpret and analyze information.
- How response of the effector works.

A **nerve** is a group of neurons (bundles of neurons) with blood vessels and connective tissue.

Sensory (afferent) nerves are made only of sensory neurons. The optic nerves for vision and olfactory nerves for smell are examples of nerves with a purely sensory function.

Motor (efferent) nerves are made only of motor neurons; autonomic nerves are motor nerves.

A **mixed nerve** contains both sensory and motor neurons. Most of our peripheral nerves, such as the sciatic nerves in the legs, are mixed nerves.

The term **nerve tract** refers to groups of neurons within the central nervous system. All the neurons in a nerve tract are concerned with either sensory or motor activity. These tracts are often referred to as white matter; the myelin sheaths of the neurons give them a white color.

Activity 5.4

Can you draw a typical nerve cell and label the parts, and explain how it functions to the class?

- The sodium channel and potassium channels on the membrane of neuron are closed.

- This state of resting neuron is called Polarized state and it is electro-negatively charged.

Depolarization or Action Potential

A stimulus above the threshold which can be initiated by mechanical, chemical and physical stimulation cause the initiation of impulse

5.1.2. The Nerve Impulse and transmission

By the end of this section, the learner will be able to;

Explain nerve impulse and transmission.

Self-questioning

Why is the presence of synapse important for neurotransmission?

What is action potential ?

How does it passes from one neuron to the other?

How does impulse passes from one

The nervous system relies on nerve impulses travelling along a neuron. Each nerve impulse is a minute electrical event that works as a result of charge differences across the membrane of the axon. The wave of positive charge inside the axon when the neuron is stimulated is known as the **action potential**.

Resting Potential

When an axon is resting, its membrane is polarized; that is, the outside is positive compared to the inside (which is negative). When the axon is not conducting an impulse, the voltmeter records a membrane potential equal to about -65 mV (millivolts), indicating that the inside of the neuron is more negative than the outside (Figure 5.4). This is called the resting potential because the axon is not conducting an impulse.

Keywords

Action potential a short- term change in the electrical potential on the surface of a cell when it is stimulated

Synapse the junction between two neurons (axon-to-dendrite) or between a neuron and a muscle

Threshold potential the voltage at which depolarization of a cell leads to generation of an action potential.

Hyperpolarization increasing neuronal membrane potential to more than its usual resting potential (making it harder to induce the cell to produce an action potential)

Refractory period a brief period following the generation of an action potential, during which a neuron is hard to re-excite

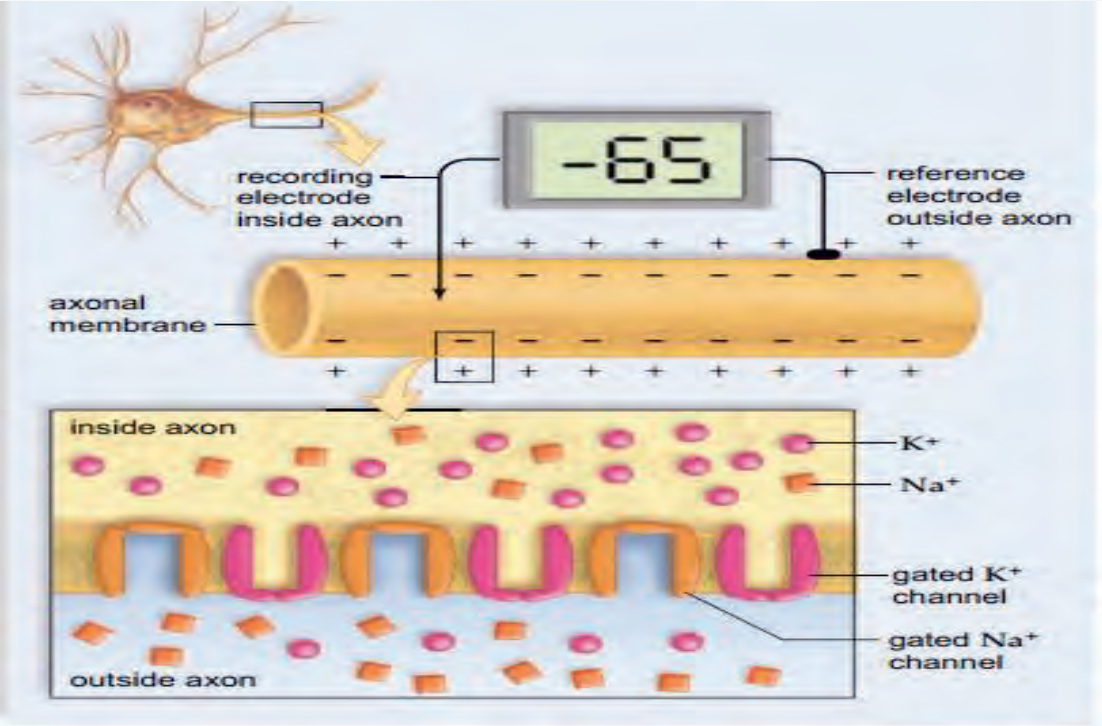


Figure 5.4 Resting potential

Polarization

- In the resting state the inside of membrane has negative electrical potential compared to outside. This difference in potential is called resting potential (about -40mv to -90mv).
- The interstitial fluid has high concentration of Na+ ion which is about 16 times higher outside the neuron than inside neuron. Similarly, the axoplasm has high concentration of K+ ion which is about 25 times higher inside than in outer interstitial fluids.
- Due to difference in Na, K concentration, the Na+ ions diffuse inside the exoplasm and K+ ions tends to diffuse outside of it.
- The membrane of neuron at resting is more permeable to K+ ion than Na+ ion. So, K+ leaves the neuron faster than Na+ enter the neuron.
- Na+and K+ are transported across the membrane against their concentration gradient by carrier protein, which is called Na-K pump and energy is used through ATP.
- The difference in permeability results in accumulation of high concentration of cation (+ve charged ion) outside the neuron compared to the concentration of cation inside.
- .Sodium channels are opened but potassium channels are closed and

Na+ions flood in through cell membrane and create a positive charge of +40mv.

- It is a very short periods that change in potential and last for 3 milliseconds.
- When an action potential occurs, the axon is said to be depolarized.
- The depolarization of the membrane stimulates the adjacent voltage channel, so the action potential passes as a wave along the length of neuron.

Depolarization: This process is started by a nerve impulse. Acetylcholine released by the axon terminal makes the sarcolemma very permeable to Na+ ions, which enter the cell and cause a reversal of charges to (-ve) outside and (+ve) inside. The depolarization spreads along the entire sarcolemma and initiates the contraction process. Folds of the sarcolemma called T tubules carry the depolarization into the interior of the muscle cell. As soon as depolarization takes place, the neuron membrane becomes very permeable to K+ ions, which rush out of the cell. This restores the positive charge outside and the negative charge inside, and is called repolarization. Then the sodium and potassium pumps return Na+ ions outside and K+ ions inside, and the neuron is ready to respond to another stimulus and transmit another impulse. An action potential in response to a stimulus takes place very rapidly and is measured in milliseconds. An individual neuron is capable of transmitting hundreds of action potentials (impulses) each second

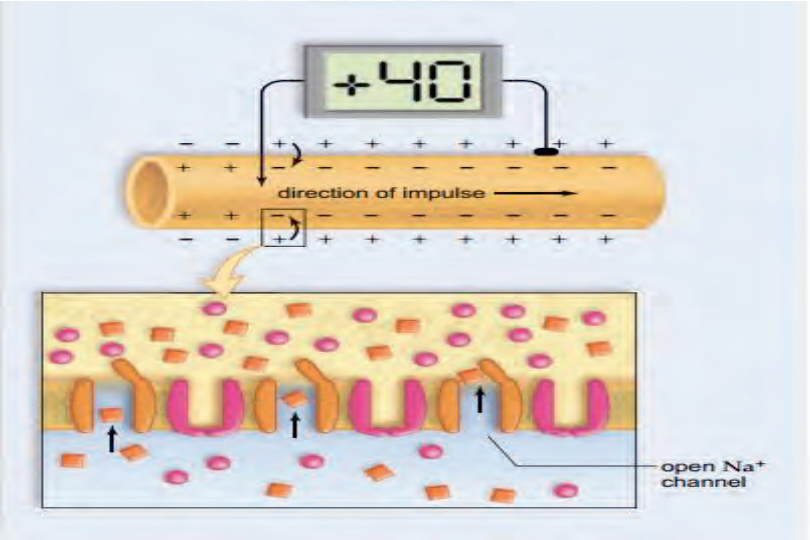


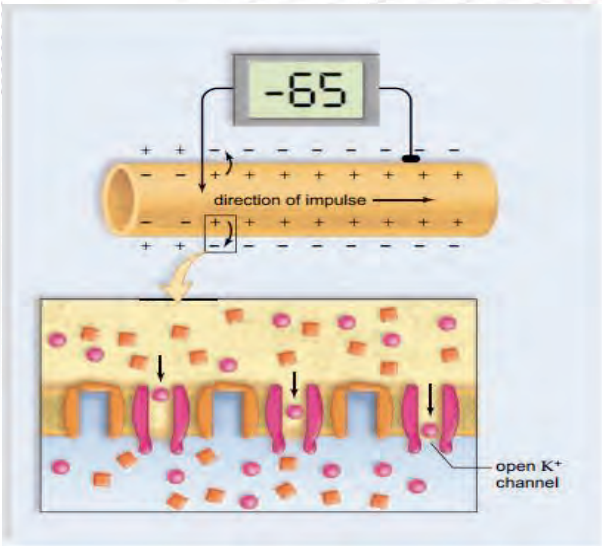
Figure 5.5 Action potential begins: depolarization occurs

Repolarization

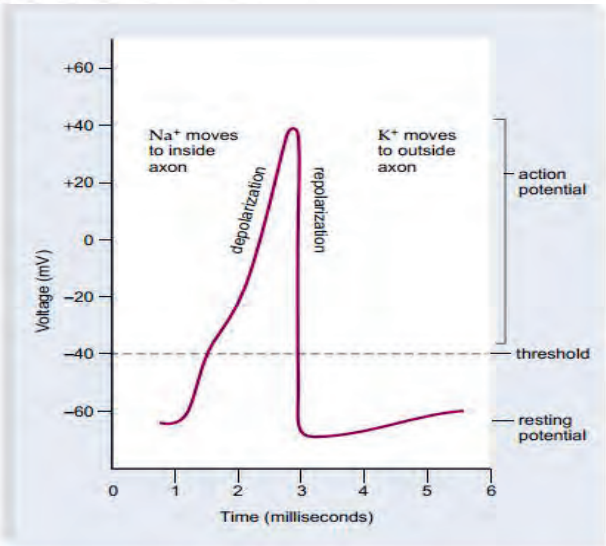
- Sodium channels are closed potassium channel are opened and K^+ions diffuse out along their concentration gradient. This starts repolarization and resting potential going to reestablish.
- At the same time nerve become less permeable for Na+than K+. So many K+ flow out and inside charge become more negative than that it was originally.
- Na-k pump starts and normal concentrations of Na and K ions are reestablished. Each pump actively transports two K+ions into the cell to every three Na+ ions transported out.
- The membrane is once again at its resting potential.

Action Potential: An action potential is a rapid change in polarity across a portion of an axonal membrane as the nerve impulse occurs. An action potential uses two types of gated ion channels in the axonal membrane.

- When the nerve fiber is conducting a nerve impulse (action potential), a change in polarity occurs across the axon's membrane. First, the inside of an axon becomes positive compared to the outside (this is called depolarization), and then the inside becomes negative again (this is called repolarization). An action potential requires two types of channels in the membrane: One channel can allow Na ions to pass through the membrane, and the other can allow K ions to pass through the membrane. During depolarization, Na ions move to the inside of the axon, and during repolarization, K ions move to the outside.



A) Action potential ends



B) Action potential graph

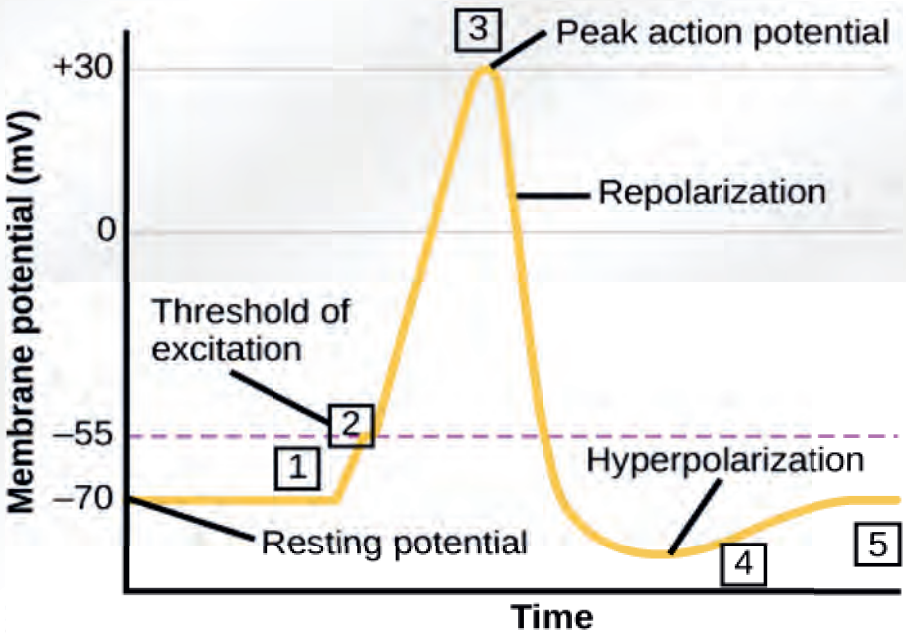


Figure 5.6 Conduction of Action Potentials

Syanapse

By the end of this section, the learner will be able to;

- Explain how impulse crosses the synaptic cleft
- Describe the function of acetylecholinestrase

Self-questioning

- How do synapses work?

Whenever one neuron ends and another begins there is a gap known as a s**ynapse**. Neuron-neuron synapses usually involve a connection between the axon of one neuron and the dendrites, cell body, or axon of a second neuron. The axon of the presynaptic neuron ends in slight swellings, the axon terminals, which hold the **synaptic vesicles** that contain neurotransmitter molecules.

The axon terminal of the **presynaptic neuron,** which conducts its action potentials *toward* the synapse, ends in a slight swelling, the **synaptic knob.** The synaptic knob contains **synaptic vesicles,** which store a specifc chemical messenger, a

neurotransmitter that has been synthesized and packaged by the presynaptic neuron. The synaptic knob comes close to, but does not touch, the **postsynaptic neuron,** whose action potentials are propagated away from the synapse. The space between the presynaptic and postsynaptic neurons is called the **synaptic cleft.**

The process by which the impulse in the presynaptic neuron signals the postsynaptic cell is called **synaptic transmission.** As a result of synaptic transmission, the presynaptic neuron stimulates or inhibits a postsynaptic cell (Figure 5.7). Synaptic transmission is a one-way process carried out by *neurotransmitters*. An impulse travels along the axon of the presynaptic neuron to the axon terminal. Most axons have several rounded synaptic knobs at their terminals, which dendrites do not ave. These knobs have arrays of membranous sacs, called synaptic vesicles, that contain neurotransmitter molecules. When an impulse reaches a synaptic knob, voltage-sensitive calcium channels open and calcium diffuses inward from the extracellular fluid. The increased calcium concentration inside the cell initiates a series of events that fuses the synaptic vesicles with the cell membrane, where they release their neurotransmitter by exocytosis.

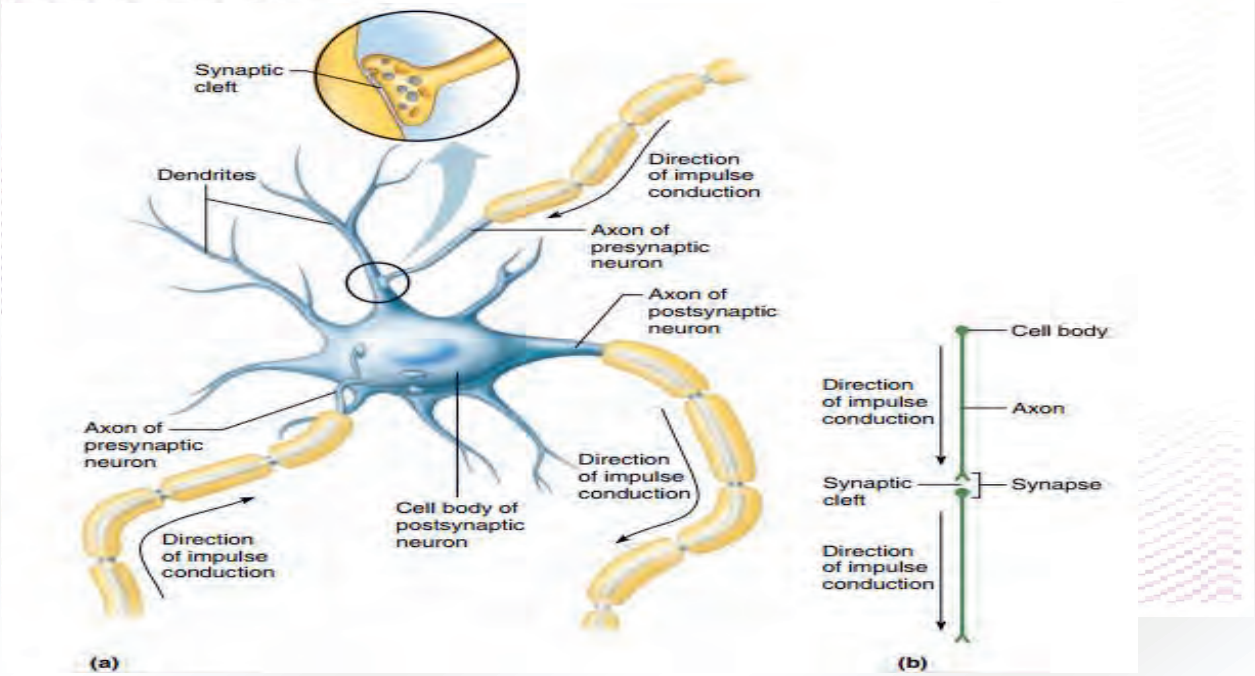


Figure 5.7 Synapsis occurs from axon terminal one neuron to the denderities or cell body another neuron

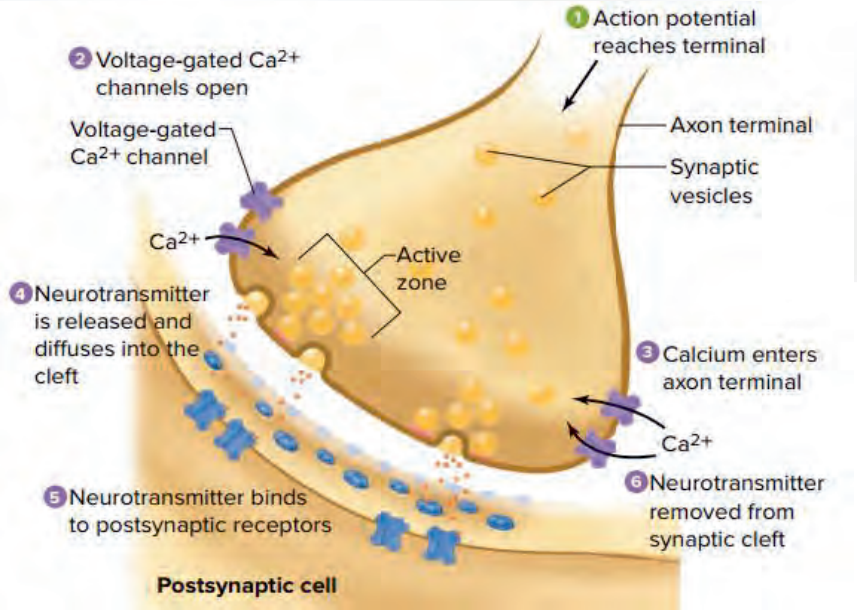


Figure 5.8 Signal transmission through a synapse.

5.1.3. Neurotransmitters

At the end of this section, the learner will be able to:

- Describe the role of neurotransmitters.

Neurotransmitters are often referred to as **the body's chemical messengers**. They are the molecules used by the nervous system to transmit messages between neurons, or from neurons to muscles. Acetylcholine (ACh) is **an abundant neurotransmitter in the human body**. It is found in both the central nervous system (CNS) and the peripheral nervous system (PNS).

An **excitatory transmitter** promotes the generation of an action potential in the receiving neuron, whereas an **inhibitory transmitter** prevents it. Whether a neurotransmitter is excitatory or inhibitory depends on the receptor it binds to.

Keywords

Excitatory transmitter promotes the generation of an electrical signal (action potential) in the receiving neuron

Inhibitory transmitter decrease the likelihood that the neuron generate action potential (action potential).

Activity 5.5

Make a small group and search from different sources about synapses and special types of synapses and answer the following questions.

a. Do we have special types of synapses?

b. What are neuromuscular junctions? What is their role? Where do we find them? Reflect your findings to the class.

5.1.4. Types of the nervous system

Activity 5.6

Search from different sources (books and the internet) about the various types of neurotransmitters and their role in the nervous system. Reflect your finding to the class.

By the end of this section, thestudent will be able to:

- Identify types of the nervous syste

Human nervous system has two main parts. These are the central nervous system (CNS), which is made up of **brain** and **spinal cord,** and the **peripheral nervous system** which consists of the nerves that branch out from the brain and spinal cord.

Keywords

Spinal cord a column of nerve tissue within the backbone

Neurons nerve cells

Sensory receptors nerve endings that can sense stimuli, e.g. pressure, pain, temperature, and start a nerve impulse

A. The Central Nervous System

The Central Nervous System (CNS) consists of two main parts: – the **brain** and the **spinal cord**.

The Brain

Self-questioning

Which parts your body systems get involved for coordination and rapid responses to the changes in the environment?

Central nervous tissue is delicate. Because of this characteristic, and because damaged nerve cells cannot be replaced, this fragile, irreplaceable tissue must be well protected. Four major features help protect the CNS from injury:

1. It is enclosed by hard, bony structures. The *cranium (skull)* encases the brain, and the *vertebral column* surrounds the spinal cord.

2. Three protective and nourishing membranes, the *meninges*, lie between the bony covering and the nervous tissue.

The meninges consist of three connective tissue layers:

• **Dura mater** – this layer lies closest to the bone of the skull and is a double layer of tough, fibrous, connective tissue. The outer layer is called the periosteal layer (the spinal cord lacks this layer), and the meningeal layer lies closest to the brain.

• **Arachnoid mater** – between the dura mater and the arachnoid mater there is a space called the subdural space. The arachnoid mater is a delicate serous membrane. The subarachnoid space is below the arachnoid mater and above the pia mater. The subarachnoid space contains CSF and is also home to some of the larger blood vessels serving the brain.

• **Pia mater** – this is a delicate connective tissue layer that clings tightly to the brain. It contains many tiny blood vessels that serve the brain.

The brain "floats" in a special cushioning fluid, the *cerebrospinal fluid (CSF)*. It is a thin fluid similar to plasma and has several important functions:

• it acts as a cushion, supporting the weight of the brain and protecting it from damage;
• it helps to maintain a uniform pressure around the brain and spinal cord;
• there is a limited exchange of nutrients and waste products between neurones and CSF.

Protected within the skull, the brain is composed of the **cerebrum**, **cerebellum**, and **brainstem (Medula)** (Figure 5.3).

Cerebrum

The **cerebrum,** also called the telencephalon, is the largest portion of the brain in humans. **Cerebrum:** is the largest part of the brain and is composed of **right** and **left** hemispheres. It performs higher functions like interpreting touch, vision and hearing, as well as speech, reasoning, emotions, learning, and fine control of movement.

The **hypothalamus** ("under the thalamus") is the center for homeostatic control of the internal environment. It receives signals about the state of the body and regulates thirst, appetite, and body temperature. It also controls sex drive and is an endocrine gland that interacts with the adjacent pituitary gland.

Thalamus

The thalamus is superior to the hypothalamus andinferior to the cerebrum. The third ventricle is a narrow cavity that passes through both the thalamus andhypothalamus. Many of the functions of the thalamusare concerned with sensation. The **midbrain** acts as a relay station for tracts passing between the cerebrum and the spinal cord or cerebellum. The tracts cross in the brain stem so that the right side of the body is controlled by the left portion of the brain, and the left portion of the body is controlled by the right portion of the brain.The brain stem also has reflex centers for visual, auditory, and tactile responses.

The **cerebellum** lies under the occipital lobe

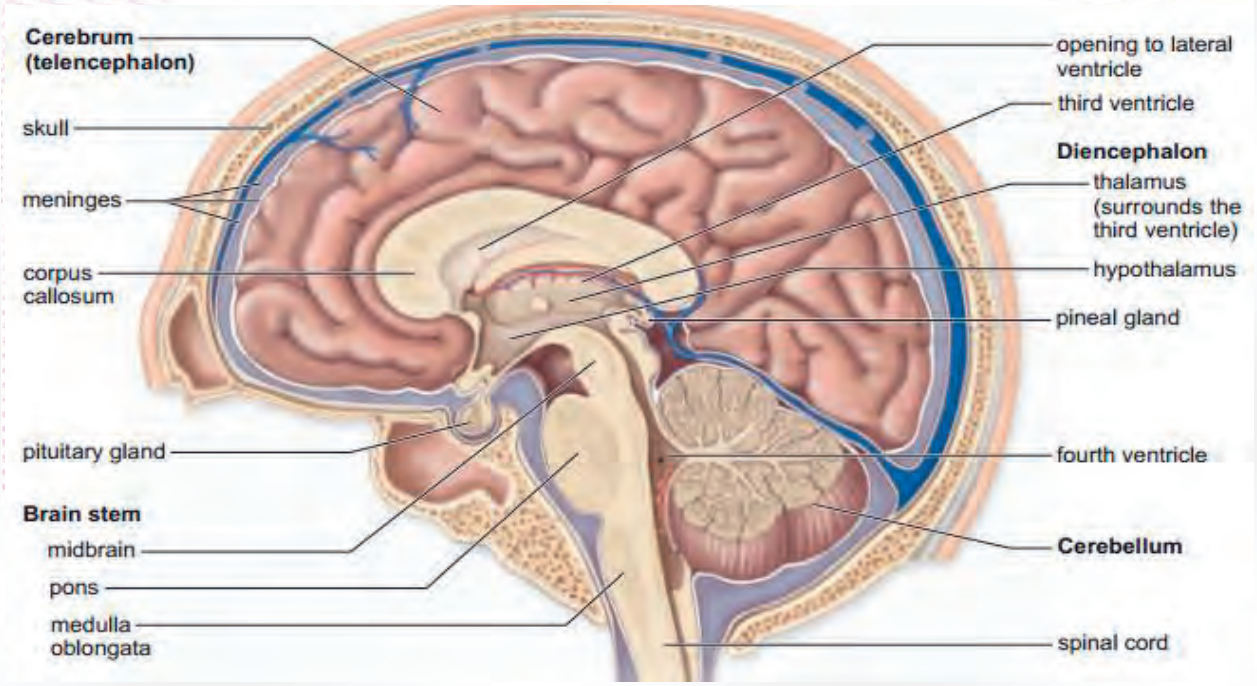


Figure 5.9 Parts of human brain

of the cerebrum and is separated from the brain stem by the fourth ventricle. It is the largest part of the hindbrain. The cerebellum receives sensory input from the eyes, ears, joints, and muscles about the present position of body parts, and it also receives motor output from the cerebral cortex about where these parts should be located. After integrating this information, the cerebellum sends motor impulses by way of the brain stem to the skeletal muscles. In this way, the cerebellum maintains posture and balance.

It also ensures that all of the muscles work together to produce smooth, coordinated voluntary movements. The cerebellum assists the learning of new motor skills such as playing the piano or hitting a baseball. New evidence indicates that the cerebellum is important in judging the passage of time.

Medulla (Brainstem)

The medulla oblongata, pons, and midbrain constitute the **brainstem**. The brainstem connects the spinal cord to the remainder of the brain and is responsible for many essential functions.

The word **pons** means "bridge" in Latin, and true to its name, the pons contains bundles of axons traveling between the cerebellum and commands.

the rest of the CNS. In addition, the pons functions with the medulla oblongata to regulate breathing rate, and has reflex centers concerned with head movements in response to visual and auditory stimuli.

The **medulla oblongata** contains a number of reflex centers for regulating heartbeat, breathing, and blood pressure. It also contains the reflex centers for vomiting, coughing, sneezing, hiccuping, and swallowing. The medulla oblongata lies just superior to the spinal cord, and it contains tracts that ascend or descend between the spinal cord and higher brain centers.

White and gray matter

The brain and spinal cord contain gray matter and white matter. **Gray matter** is primarily made up of neuron cell bodies. **White matter** consists of bundled axons. In the spinal cord, white matter forms the outer layer, reflecting its role in linking the CNS to sensory and motor neurons of the PNS. In the brain, white matter is predominantly in the interior, where signaling between neurons functions in learning, feeling emotions, processing sensory information, and generating

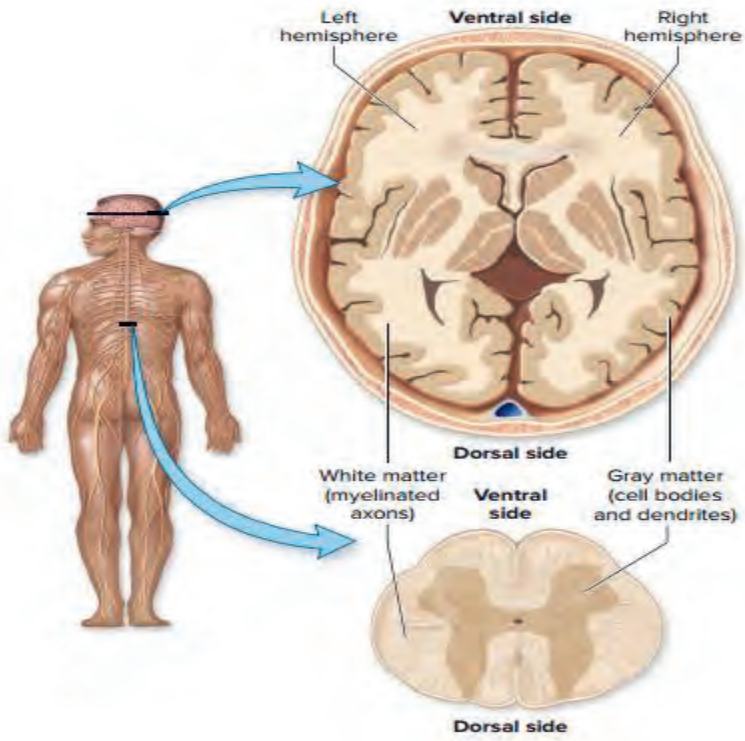


Figure 5.10 White and Gray matter of a brain

Keywords

Fore brain the large frontal area of the human brain

Grey matter areas in the brain and spinal cord that consist of unmyelinated nerve cells

White matter areas of the brain and spinal cord composed mainly of long-range myelinated axons

Affector (afferent) neuron that sends impulses from organs to the spinal cord and brain

Effector (efferent) neuron that sends impulses from the brain and spinal cord to

The spinal cord

The spinal cord has a much simpler structure than the brain. It is a tubular structure composed of the nervous tissue that extends from the brainstem and continues distally before tapering at the lower thoracic/upper lumbar region as the conus medullaris (the terminal end of the spinal cord). The spinal cord runs out from the brain down the body. The spinal cord is encased and protected by the vertebrae making up the spine. The majority of nerves come out of the spinal cord are known as the **spinal nerves**. They stretch to the arms, legs, trunk and to the rest of the body (Figure 5.4). In the spinal cord **the grey matter** is located in the middle whereas the **white matter** is found on the outside (Figure 5.5). At regular intervals along the spinal cord there are entrance points for **affector** nerves that bring information into the CNS and exit points for **effector** nerves carrying instructions from the CNS.

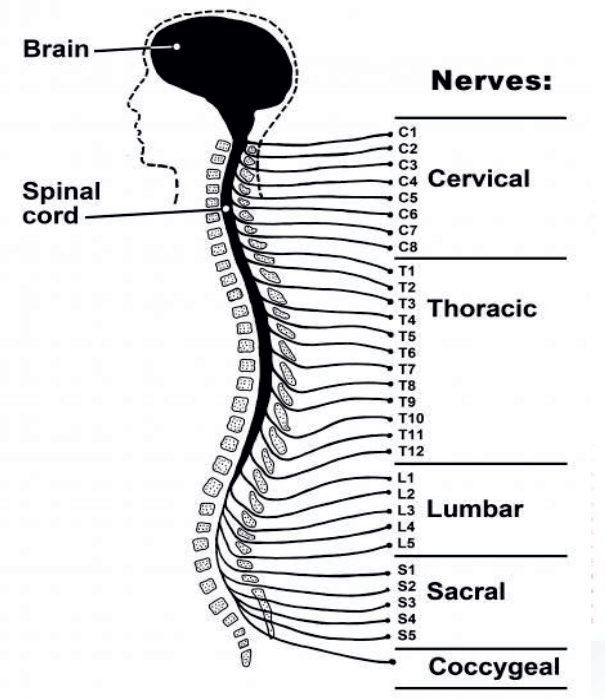


Figure 5.11 The spinal cord and spinal nerves

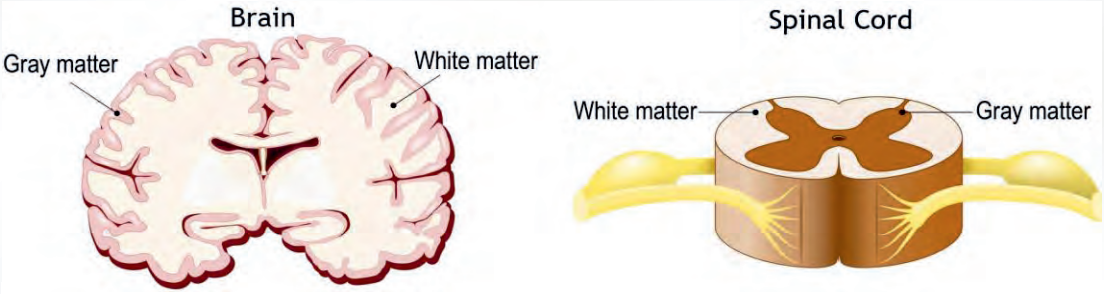


Figure 5.12 The cross-section of the CNS showing the position of grey and white matters.

Dura mater – This is the thick outermost covering (meninges) of the brain and spinal cord. It is the layers of connective tissue that make up the meninges of the brain (dura, arachnoid, and pia). It is the outermost layer of the three meninges that surround and protect the brain and spinal cord

Activity 5.7

Make a small group and read from different books and other sources about:

1. Cranial and spinal nerves; the names of the different types of the cranial and spinal nerves and the role of these nerves in the human nervous system.

2. The opposite sides of the brain (the right and left hemispheres of the brain), their basic difference in function and how they work and control your body. Report your work to the class.

Pia mater – This is the innermost covering of the spinal cord. Intimately adhered to its surface, the pia mater stabilizes the spinal cord through lateral extensions of the pia called the denticulate ligaments, extending between the ventral and dorsal roots unto the dura mater.

The Peripheral Nervous System

The Peripheral Nervous System (PNS) is the division of the nervous system that contain all the nerves that lie outside of the central nervous system. The peripheral nervous system is subdivided into the afferent division and the efferent division . The afferent division of the PNS carries signals to the CNS and includes all the neurons that transmit sensory information from their receptors. The efferent division of the PNS carries signals from the CNS to the muscles and glands, which act as effectors to bring about the desired response. In mammals, 31 pairs of spinal nerves carry signals between the spinal cord and the body trunk and limbs, and 12 pairs of cranial nerves connect the brain directly to the head, neck, and body trunk. The efferent division of the PNS is

further subdivided into the somatic nervous system and the autonomic nervous system.

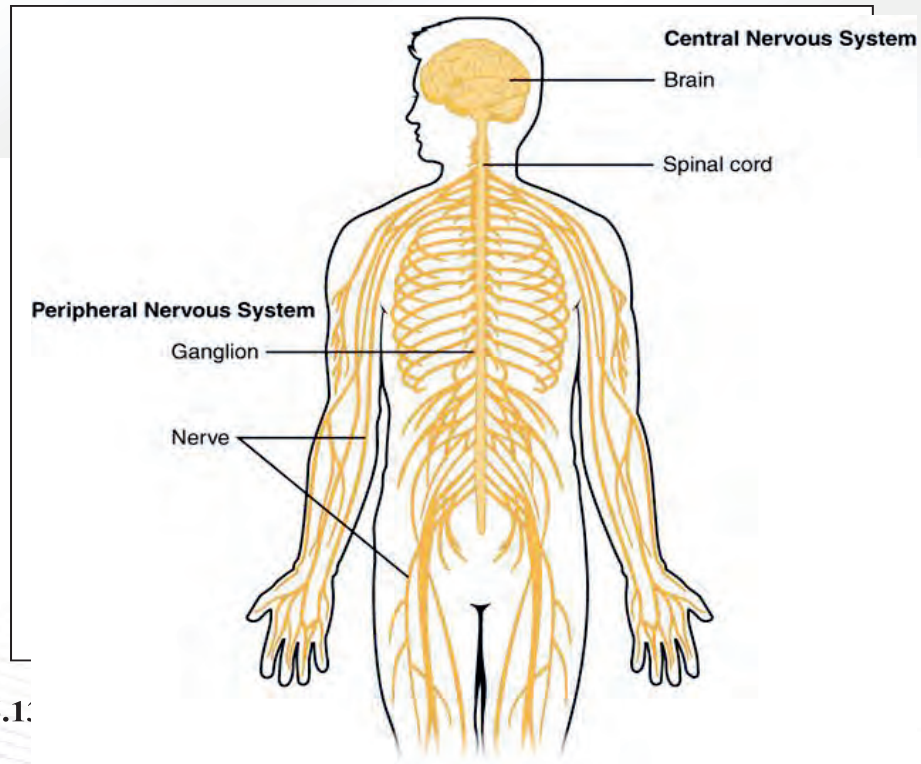


Figure 5.1

The Somatic Nervous System

The somatic system is the part of the PNS that is responsible for carrying out sensory and motor information to and from the central nervous system. The somatic nervous system derives its name from the Greek word *soma*, which means "body." The somatic system is responsible for transmitting sensory information as well as for voluntary movement.

The Autonomic Nervous System

The autonomic system is part of your PNS that is responsible for regulating involuntary body functions, such as blood flow, heartbeat, digestion, and breathing. In other words, it is the autonomic system that controls aspects of the body that are usually not under voluntary control. This system allows these functions to take place without the need to consciously think about what is happening. The autonomic system is further divided into two branches:

Sympathetic system: By regulating the 'flight-or-fight' response, the sympathetic system prepares the body to expend energy to respond to environmental threats. When action is needed, the sympathetic system triggers a response by accelerating heart rate and increasing breathing rate, boosting the blood flow to

muscles, activating sweat secretion, and dilating the pupils.

Parasympathetic system: This helps maintain the normal body functions and conserve physical resources. Once a threat is recognized, this system will slow the heart rate, slow breathing, reduce blood flow to muscles, and constrict the pupils. This allows us to return our bodies to a normal resting state.

Parasympathetic system: This helps maintain the normal body functions and conserve physical resources. Once a threat is recognized, this system will slow the heart rate, slow breathing, reduce blood flow to muscles, and constrict the pupils. This allows us to return our bodies to a normal resting state.

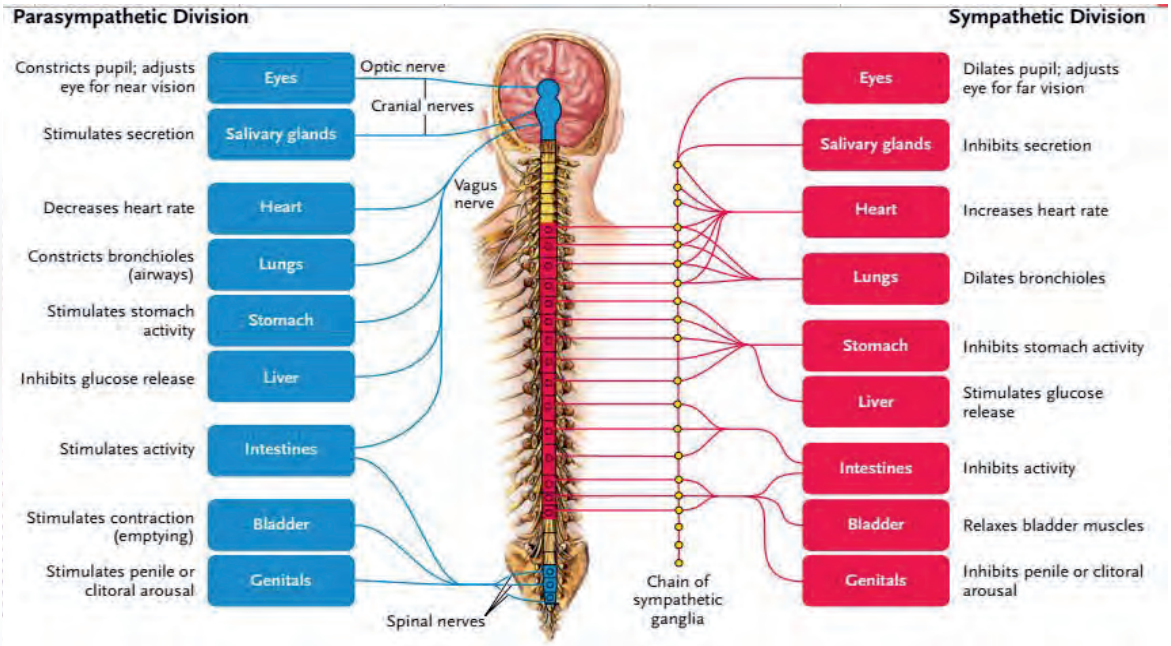


Figure 5.14 The Autonomic Nervous System

5.1.6. Reflex action

At the end of this section the learner will be able to:

- Define reflex action
- State the types of reflexes with examples.

A **reflex action** is a sudden, automatic and uncontrolled response of parts of the body or the whole body to the external stimuli. They are usually involved in helping us to avoid danger or damage. When the body is in danger, it can respond to the situation, without conscious, thought. This causes a faster response, preventing or minimizing damage to the body. This is known as reflex action. A reflex action is an automatic response to a stimulus.

Keywords

Reflex action- automatic, instinctive, unlearned reactions to stimuli

Voluntary- actions that involve conscious thought

Reflex arc neural path of a reflex

Reflex Arc

The parhway of neurons involved in a reflex action is known as reflex arc. Most reflexes follow the same steps between the stimuli and the response.

One of the simplest situations where impulses cross synapses to produce action is in the reflex arc. A reflex action is an automatic response to a stimulus. (A stimulus is a change in the external or internal environment of an organism.) It provides a means of rapidly integrating and co-coordinatinga stimulus with the response of an effector (a muscle or a gland) without the need for thought or a decision.

A reflex arc is the pathway that

Self-questioning

- Why reflexes can happen so quickly?
- Do you think that all reflexes are simple?
- How reflexes are so important for keeping us safe and helping us to learn
- What are the differences between voluntary and reflex action?

nerve impulses travel when a reflex is elicited, and there are five essential parts:

1. **Receptors**:- detect a change (the stimulus) and generate impulses.

2. **Sensory neurons**:-transmit impulses from receptors to the CNS.

3. **Central nervous system:-**contains one or more synapses (interneurons may be part of the pathway).

4. **Motor neurons:-**transmit impulses from the CNS to the effector.

5. **Effector**: -performs its characteristic action.

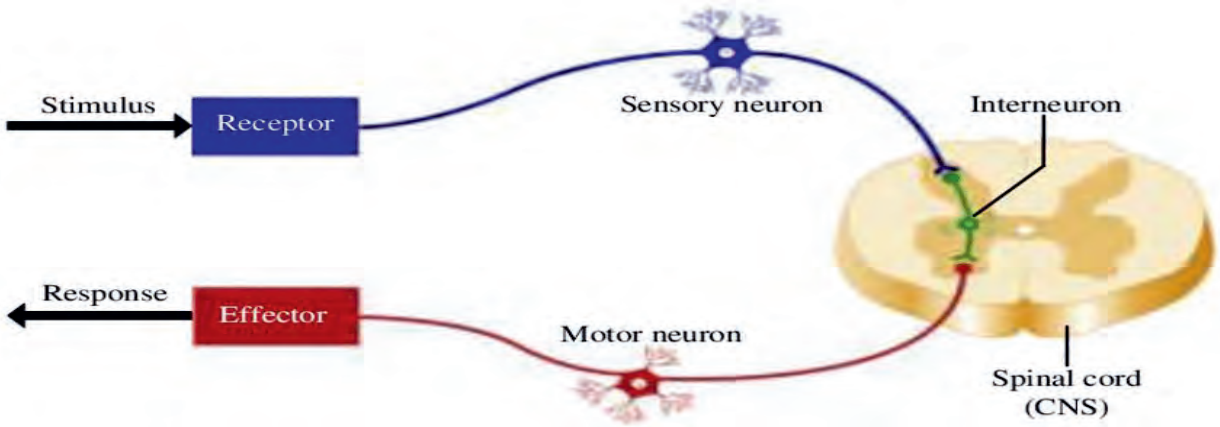


Figure 5.15 Path way for a nerve impulse in reflex action

- Let us now look at the reflex arc of a specific reflex, the patellar (or knee-jerk) reflex, with which you are probably familiar. In this reflex, a tap on the patellar tendon just below the kneecap causes extension of the lower leg. This is a stretch reflex, which means that a muscle that is stretched will automatically contract.

Keywords

Dorsal root- root at the back of the spinal cord

Ventral root- root at the front of the spinal cord

- As shown in the Figure 5.15:
- Impulses from a sensory receptor in the skin pass along an affector neuron to the central nervous system – the spinal cord.
- The neuron enters the spinal cord through the dorsal root.
- When an impulse from the affector neuron arrives in the synapse with a short relay neuron a transmitter is released, which causes an impulse to be sent along the relay neuron.

When the impulse reaches the synapse between the relay neuron and an effector

neuron returning to the arm again another transmitter chemical is released.

This starts impulses travelling along the effector neuron to the organ (effector), which brings about change. The effector neuron leaves the spinal cord by the ventral root. In this example the impulses arrive in the muscles of the upper arm, causing them to contract and move your hand upwards sharp.

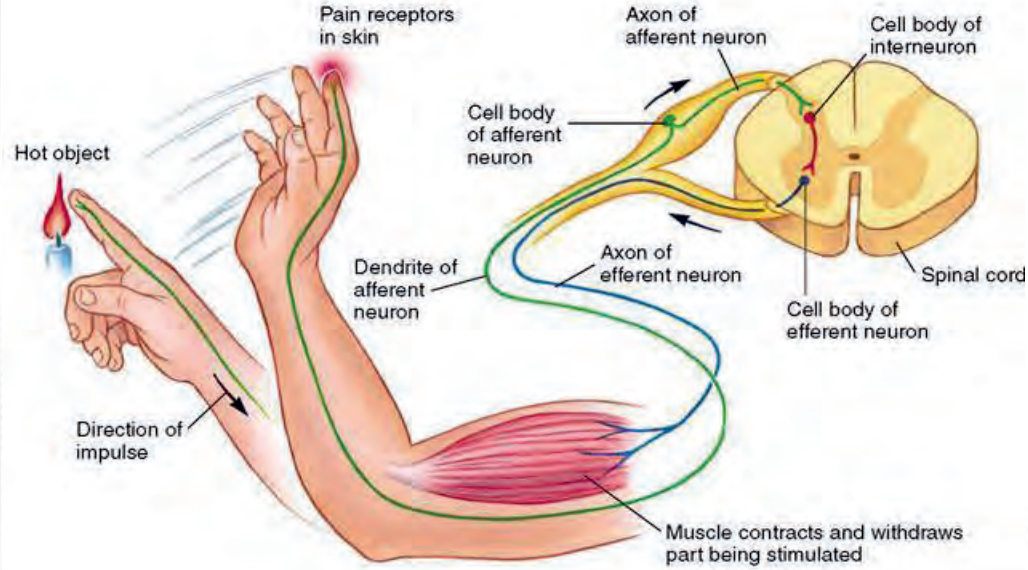


Figure 5.16 The reflex action

Some reflexes are important for avoiding injury, but the knee-jerk and ankle-jerk reflexes are important for normal physiological functions. For example, the knee-jerk reflex helps a person stand erect. If the knee begins to bend slightly when a person stands still, the quadriceps femoris is stretched, and the leg straightens.

The spinal cord has a much simpler structure than the brain. It is a tubular structure composed of the nervous tissue that extends from the brainstem and continues distally before tapering at the lower thoracic/upper lumbar region as the conus medullaris (the terminal end of the spinal cord). The spinal cord runs out from the brain down the body. The spinal cord is encased and protected by the vertebrae making up the spine. The nerves that originate from the spinal cord are known as the **spinal nerves**. They stretch to

the arms, legs, trunk and to the rest of the body (Figure 5.4). In the spinal cord **the grey matter** is located in the middle whereas the **white matter** is found on the outside (Figure 5.5). At regular intervals along the spinal cord there are entrance points for **affector** nerves that bring information into the CNS and exit points for **effector** nerves carrying instructions from the CNS.

Activity 5.8

Make a small group and read from different books and other sources about:

1. Cranial and spinal nerves; the names of the different types of the cranial and spinal nerves and the role of these nerves in the human nervous system.

2. The opposite sides of the brain (the right and left hemispheres of the brain), their basic difference in function and how they work and control your body. Report your work to the class.

Self-questioning

Distinguish voluntary and reflex action? Can you tell your friend one example to each actions?

Activity 5.9 Investigating reaction time

The length of time it takes you to recognize a stimulus and react to it is your reaction time. These are very important in many situations – for example, when you are driving, or at the start of a race. Some people react more quickly than others and you can train yourself to speed up. In this investigation you will be looking at reaction times by measuring how quickly your partner catches a meter ruler when you let it fall. If you collect all the data for the class, you can produce a graph to show the range of reaction times for your science group, and also do some statistical analysis to find the average, median and mean reaction times for your class.

You will need:

• A meter ruler (or a stick and a ruler)

Method

1. Work in pairs, with one partner holding the ruler and recording the distance and the other catching.
2. Hold the ruler so that your partner's hand is level with the 10 cm mark. They should be able to see the ruler and your hand.
3. Warn them that you will soon be dropping the ruler and, after a few seconds, let go.
4. Repeat this three times and calculate the average distance the ruler travelled before your partner caught it.
5. Swap roles.
6. Draw up a table and collect the results for the whole class.
7. Write up your investigation, including a graph to show the distribution of reaction rate across the class.
8. How could you develop or refine this investigation?

The key point about a reflex action is that the messages do not reach a conscious area of your brain before instructions are sent out to take action. Many reflexes involve the spinal cord, whereas others involve the brain. They involve three types of neuron affector neurons, relay neurons and effector neurons. Relay neurons (interneurons with short axons) connect the

affector and effector neurons directly in the CNS, without input from other areas. The receptors, neurons and effectors involved are referred to as a **reflex arc**. The brain and spinal cord act together as a coordinators that process the information coming from sensory receptors and neurons and instruct effector neurons and effectors to react.

Activity 5.10 The Knee jerk reflex

You can demonstrate a simple spinal reflex used by doctors.

1. Work in pairs.
2. One person sits down with one leg loosely crossed over the other.
3. The other hits the crossed leg just below the knee cap (patella) gently but firmly. Use the edge of the hand, a special hammer or the edge of a ruler to do this. It should not hurt!
4. This hits a ligament which stretches a muscle. This is picked up by stretch receptors setting up a reflex arc. The impulse travels to the spinal cord and back to the quadriceps muscles in the thigh. These contract, causing the lower leg to jerk upwards and outwards as the leg straightens. It drops straight back into its normal position.
5. Change places and repeat!

Activity 5.11

1. Make a small group and search from books and other materials (the internet) about Ivan Pavlov's experiment on dog. Report your finding to the class.

2. Take one example of a reflex action. Draw a diagram to show this reflex arc, label it carefully and discuss your work in the class

At the end of this section, the learner will be able to:

- Illustrate the effects of drug abuse on nervous systems with local and international examples.

Self-questioning

1. What is a drug?
2. Can you define
   a. what drug use mean?
   b. What drug abuse mean?

5.1.7. Drug abuse

Drugs are substances that change a person's mental or physical state. They can affect the way the brain works, how you feel and behave, your understanding and your senses. This makes people, especially young people develop unpredictable and dangerous behavior.

In every society there are certain drugs which are used for medicine and there are others which are used for pleasure. Usually some of these substances are socially acceptable and others are illegal. The status of a drug may be related to its effect on people, or it may be simply down to the history of its use. Most of the drugs being used for medicine affect our bodies. Some of the drugs used for pleasure tend to have a distinct effect on our minds. Drug (substance) use is when a substance is used to the extent that affects the brain and/or body function and mental activity.

Keywords

Addicted compulsively or physiologically dependent on something habit-forming

Withdrawal symptoms a set of unpleasant effects upon the body caused by a sudden stopping of using a drug

Legal drugs are used for the mild pleasure they bring, to be sociable and as a habit. People may start to use illegal drugs for the same reasons. **Drug (or substance) abuse** is when a person uses a substance to the point of excess and/or dependence. When drugs are taken in excess they cause a serious health risk and even death. Drug dependence is when a person use a drug again and again and become **addicted**. Addiction is marked by a change in behavior caused by the biochemical changes in the brain after continued substance abuse.

Activity 5.12

Read from different books and other resources about drug addiction, drug dependence and withdrawal symptoms. Reflect your finding to the class.

Substance use disorder (SUD) or drug addiction is a disease that negatively affects a person's brain and behavior. A person can become obsessed with any legal or illegal drugs. Some people can get addicted to certain medications. This addiction gradually starts developing when the individual continues to consume the drug despite the impairment it causes.

Nicotine, marijuana and alcohol are commonly misused drugs in today's world.

Drug abuse, of both legal and illegal substances, is becoming more of a public health problem. School surveys have shown that alcohol, khat and tobacco are substances widely used in Ethiopia. Alcohol, khat and tobacco are legal drugs in Ethiopia but cannabis is illegal. Drugs such as lysergic acid diethylamide (LSD), ecstasy, cocaine and heroin are illegal but rarely used in Ethiopia. Khat, alcohol and tobacco are linked to a wide range of health problems. The health issues linked to these drugs are mainly the result of their effect on the systems of the body.

Activity 5.13

Discuss in small group and list the three most commonly abused substances by young people in Ethiopia.

Smoking

The addictive drug in cigarette smoke is **nicotine**, which affects the brain and produces a sensation of calm, well-being and being able to cope with. However, it is very physically addictive. Unfortunately cigarette smoke also contains many very harmful chemicals, and these are linked to a number of very serious health problems.

What is dopamine?

Dopamine is a chemical released in the brain that makes you feel good. Having the right amount of dopamine is important both for body and brain. Dopamine helps nerve cells to send messages to each other. It's produced by a group of nerve cells in the middle of the brain and sends out messages to other parts of the brain. Within seconds of inhaling cigarette smoke, nicotine causes the release of dopamine in the brain, which gives people a good feeling. Over time, the brain begins to crave that feeling from nicotine and people need to use more and more tobacco to get that same good feeling.

How does nicotine use lead to addiction?

Nicotine releases a chemical called dopamine in the same regions of the brain as other addictive drugs. It causes mood-altering changes that make the person temporarily feel good. Inhaled smoke delivers nicotine to the brain within 20 seconds, which makes it very addictive.

Figure 5.17 Cigarette is an addictive drug

Alcohol

Alcohol is one of the drugs most commonly used in Ethiopia. Alcohol, like other drugs, has a powerful effect on the brain, producing pleasurable feelings and blunting negative feelings. These feelings can motivate some people to drink alcohol again and again, despite possible risks to their health and well-being. Alcohol addiction is a chronic relapsing disorder associated with compulsive alcohol drinking, the loss of control over intake, and the emergence of a negative emotional state when alcohol is no longer available. Alcohol use disorder (AUD) is a condition characterized by an impaired ability to stop or control alcohol use despite adverse social, occupational, or health consequences

Activity 5.14

Make a small group and search from books and other resources about some of the harmful chemicals found in smoking cigarettes and diseases that are caused as a result of smoking. Report your finding to the class.

Figure 5.18 Alcohol is addictive and poisonous

Activity 5.15

Read books and other sources about how alcohol can directly and/or indirectly affect the health of young people. Present your findings to the class.

Khat

Catha edulis (Khat) is a plant grown commonly in the horn of Africa. The leaves of khat are are chewed by people for it is stimulant. Its young buds and tender leaves are chewed to attain a state of euphoria and stimulation. Khat contain a drug that affects the brain. The plant has a stimulant effect similar to amphetamine, cocaine or very strong coffee depending on how much it is consumed. Many people can develop a tolerance to it over time, as well as dependence and addiction. Because of this, it is important to know what khat is, how it affects the body and how to treat a khat addiction. Khat contains a drug that affects the brain. Chewing the leaves of the evergreen shrub releases an amphetamine-like stimulant. The drug **cathinone** from the khat leaves is absorbed into the bloodstream through the membranes lining of the mouth and the stomach. It acts quickly, within 30 minutes of time, before it is broken down and removed by the liver. When addicted people cannot get the drug, feel depressed, tired and unable to concentrate.

Figure 5.19 A monoculture of Khat in Ethiopia

Cannabis (marijuana)

Cannabis is a plant that contains 400 known chemicals, 60 of which are the cannabinoids, unique to the plant. The most potent is delta-9-tetrahydrocannabinoid (THC). THC is known to affect the brain cells that are responsib

Keywords

Cannabis/marijuana drug made from the cannabis plant

Hallucinogens psychotoxic drugs that affect the mind in a way that produces distorted sensations abnormal in content

Activity 5.16

1. Search from different sources (books, the internet) about the economic importance of khat and its negative effect in damaging the economy. Report your findings to the class.

2. Can you list some of the relationship between unprotected sex, HIV/AIDS infection and Khat? How?

le for memory, emotion and motivation. Cannabis is usually smoked but it can also be eaten, whenit has a much stronger effect because your liver converts it into a much more powerful drug. It can make you feel a great sense of wellbeing and relaxation, happy and euphoric – and this is why people use it. It is a mild hallucinogenic drug. **Hallucinogens** are drugs that produce vivid waking dreams, where the user sees or hears things that are not really there, or has a distorted view of the world. However, many people find the effect of the drug a very unpleasant and disturbing experience. The effect of cannabis is very variable. It affects different people in different ways, and even the same person can react very differently depending on how it is used. Cannabis is illegal in Ethiopia.

Activity 5. 17

Make a small group and work on the following question:

What are the health and social effects of drug abuse on individuals, families and communities? Report your answers to the class.

5.2. Sense organs

At the end of this section, the learner will be able to:

- Discuss the structure and function of skin
- Draw taste sites on the tongue
- Indicate the different taste sites on a diagram of tongue correctly.
- Explain the structure and functions of nose
- Draw the structure of the human eye
- Label the structure of the human eye on a diagram correctly
- Explain the functions of the human eye
- Explain the way the eye sees things
- Identify common eye defects and their causes in humans
- Draw the structures of the human ear
- Indicate parts of human ear on a diagram
- Label the structures of the human ear
- Describe the functions of the human ear

5.2.1. Skin

Self-questioning

- What are the functions of human skin.
- What is the average weight of a human skin?

The skin is one of the largest organs in the human body in surface area and weight. It is a remarkably complex organ which carries out a number of important functions in human body. It gives you senses of touch, temperature and pain.

The skin:

- Contains a huge variety of sense organs (touch, temperature, pressure, pain).
- Forms a waterproof layer around the body tissues, which protects against the loss of water by evaporation and prevents gaining water by osmosis while swimming in the river or wash.
- It protects the body from the entry of bacteria and other pathogens.
- It protects the body from damage by UV light.
- It is an excretory organ (nitrogenous wastes are lost with the sweat).
- It is vital in controlling the body temperature.

Basic components of the human skin

Keywords

Hypodermis the lower fatty layer of skin which helps to

insulate the body against heat loss

Dermis the middle layer of skin, which is made up of blood vessels, lymph vessels, hair follicles, and sweat glands

The human skin is the largest organ of the body, with a total area of about 20 square feet. The skin protects us from microbes and elements, helps regulate body temperature, and permits the sensations of touch, heat, and cold. Skin has three main layers. These are **epidermis, dermis** and **hypodermis.**

Activity 5. 18

Form a small group. Each group needs to search for human skin model or picture and discuss the basic parts of the skin. Then present your small group discussion to the class.

- The **epidermis**, the outermost layer of skin, provides a waterproof barrier and creates our skin tone.
- The **dermis**, beneath the epidermis, contains tough connective tissue, hair follicles, and sweat glands.
- The deeper subcutaneous tissue (**hypodermis**) is made of fat and connective tissue.

The lower layer, the **hypodermis**, contains fatty tissue which is both an energy store that acts as an insulation layer, protecting against heat loss. The middle layer or **dermis** contains the blood vessels, the sweat glands, the sensory receptors and the hair follicles. This layer is closely involved in temperature control in homeostasis and in your sense of touch. The upper layer or **epidermis** is made up of dead cells. **Keratinocytes**, **melanocytes** and **langerhans cells** are some of the important cells found in the epidermis**.** Keratinocytes- produce the protein known as **keratin**, the main component of the epidermis. Keratin makes up hair, nails, and the surface layer of the skin. Keratin is what forms the rigidity of your skin and helps with the barrier protection that your skin offers. **Melanocytes** produce skin pigment, which is known as **melanin**. **Langerhans cells**, which prevent things from getting into your skin. Epidermal layer of the skin stop water loss and also protect against the entry of pathogens.

The **dermis** is a complex combination of blood vessels, hair follicles, and sebaceous (oil) glands. In the dermis, there are collagen and elastin proteins necessary for skin health because they offer support and elasticity (the skin's ability to go back to its original state after being stretched). **Collagen** is the most plentiful protein in the skin, making up 75-80% of the skin. Collagen and elastin are responsible for warding off wrinkles and fine lines. Over time, the environment and aging reduce the body's ability to produce collagen. It is the dermis which is particularly involved in the homeostatic mechanisms of the skin.

The thickness of the epidermis and dermis may vary. Due to variation in the thickness the skin can be categorized as **thick** and **thin**. Thin skin covers most of the body and can vary in thinness, with the thinnest skin covering the eyelids. Thick skin is present on the soles of the feet and palms of the hands. In addition to differing thicknesses, the skin also differs in what is available in the layers. For example, thick skin has no hair follicles or sebaceous glands, whereas thin skin does.

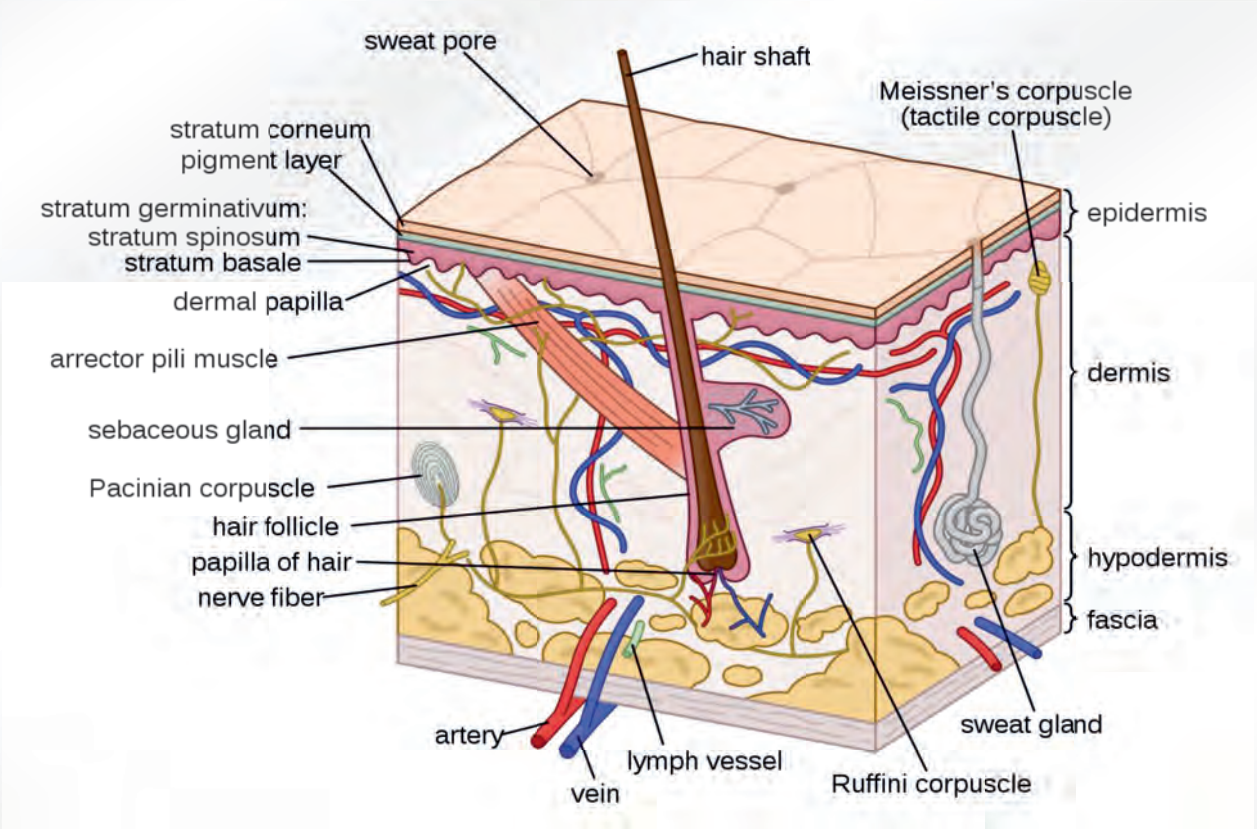


Figure 5.20 Part of the human skin

Activity 5.19

Read from different sources about human skin and report your finding to the class.

1. How a human skin color is influenced by a number of pigments.

2. List some of the skin disorders.

Activity 5.20

Investigating the sense of touch and temperature

1. Touch:

You are going to investigate the sense of touch in different areas of the skin.

You will need:

• a fine ballpoint or felt pen

• a bristle mounted on wooden holder or blunt seeker or fine piece of wire or very sharp pencil

2. Method

1. Work in pairs. Take turns to carry out the investigation.

2. With the pen, draw a grid of 25 squares on the back of your partner's hand. Each square should be 2 mm x 2 mm.

3. Draw an identical grid on paper and label it with the name of the subject and the area of the body.

4. The subject should close their eyes or look away – they must rely on the sense of touch alone. Ask them to say Y ES when they feel a touch.

5. Press the tip of the bristle against the skin in one of the squares until it just bends, or touch the skin with the blunt seeker as gently as possible. Touch each of the squares in turn, marking on your paper each one that gives a positive response.

6. Now try other areas of the skin that you might expect to be more or less sensitive,

e.g. the palm of the hand, the arm, the leg, the foot, etc.

7. Once you have tested three different areas, swap roles.

8. Are some parts of the skin more sensitive than others? W rite up your experiment along with the results and explain your observations as well as you can.

2. Temperature:

Is your sense of temperature absolute – or comparative? In other words, are your

5.2.2. The Tongue

The tongue is a muscular organ in the mouth. The tongue is covered with moist, pink tissue called mucosa. Tiny bumps called **papillae** give the tongue its rough texture. Thousands of taste buds cover the surfaces of the papillae. Taste buds are collections of nerve-like cells that connect to nerves running into the brain.

The tongue is anchored to the mouth by webs of tough tissue and mucosa. The tether holding down the front of the tongue is called the frenum. In the back of the mouth, the tongue is anchored into the hyoid bone. The tongue is vital for chewing and swallowing food, as well as for speech.

Activity 5.21

Identifying parts of human skin

You will need

- A light microscope
- A prepared slide of human skin

Method

1. Using the techniques for using a light microscope, examine your slide of the skin and identify as many features as possible.
2. Draw and label section through the skin.
3. Identify and draw higher magnification details of particular tissues such as the sweat gland, any sense organs, etc.

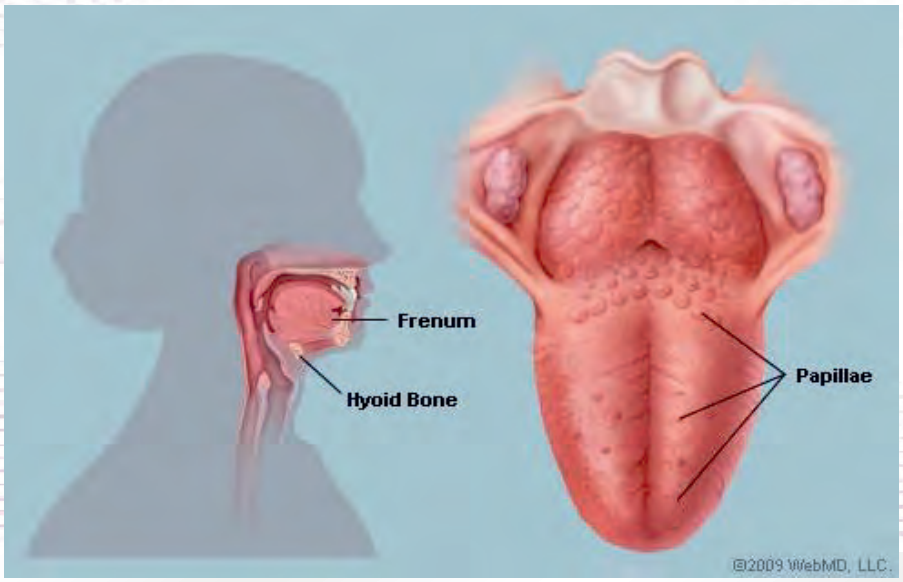


Figure 5.21 The human tongue

The sensory receptors of the tongue and those found in the nostrils are sensitive to solutions of certain chemical substances. The sensory receptors of taste are located on the upper surface of the tongue, and to a lesser extent on the surface of the throat. The receptors for smell are located in the upper parts of the nasal passages. There are five basic taste sensations. The first four are sweet, sour, bitter and salt. We have known too much about these for many years. Scientists have also discovered a fifth taste called umami (a very savoury flavour found in foods such as meat, cheese, broth and mushroom). For many years it was thought that the receptors for the four known senses had their areas of greatest concentration on different parts of the tongue. It has now been clearly shown that in fact all of the five different taste organs are spread out all over the tongue, although some of them may seem to be in a greater concentration in certain places.

Activity 5.22

Read from various sources about the tongue and reflect to the class the following questions.

1. Why do we see variation in some people in response to the same stimulus?

2. Explain why the map used in the Figure 5.19 below is wrong.

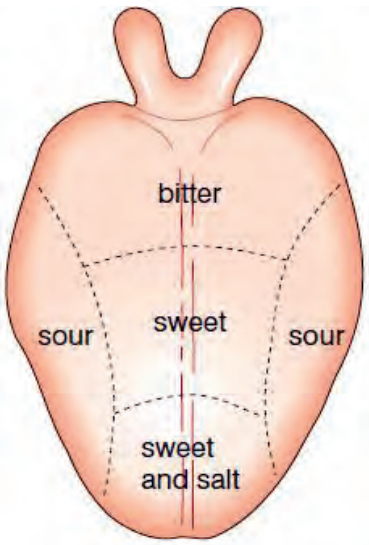


Figure 5.22 The main taste areas of the tongue that has been taught for many years.

5.2.3. The Nose

The human nose is a sense organ of smell. Another word for smell is **olfaction**. The olfactory receptors in the nose help to identify food, mates, predators, and provides both sensual pleasure in the odor of flowers and perfume, as well as warnings of danger. For example, spoiled food, fire or chemical dangers. For both humans and animals, it is one of the important means by which the environment communicates with us. Another function of the nose is the conditioning of inhaled air, which the nose makes it more humid and warmer. Hairs inside the nose prevent large particles from entering the lungs.

Anatomy and Physiology

- The nasal passages not only allow the passage of air for respiration through the nose but also warm and filter the air.
- The nasal concha or turbinate bone is a long, narrow and curled bone shelf that protrudes into the breathing passage of the nose. In humans, the turbinates divide the nasal airway into four groove like air passages, and are responsible for forcing inhaled air to flow in a steady, regular pattern around the largest possible surface of cilia and climate controlling tissue.

How do you smell?

Specialized receptor cells of the olfactory epithelium detect and recognize smells. The air passes through the nasal cavity and through a thick layer of mucus to the olfactory bulb. The olfactory bulb is situated in the forebrain. The smells are recognized here because each smell molecule fits into a nerve cell like a puzzle piece. The cells then send signals to the brain via the olfactory nerve. The brain then interprets those molecules as the sweet flowers, or the curdling milk that you have held up to your nose.

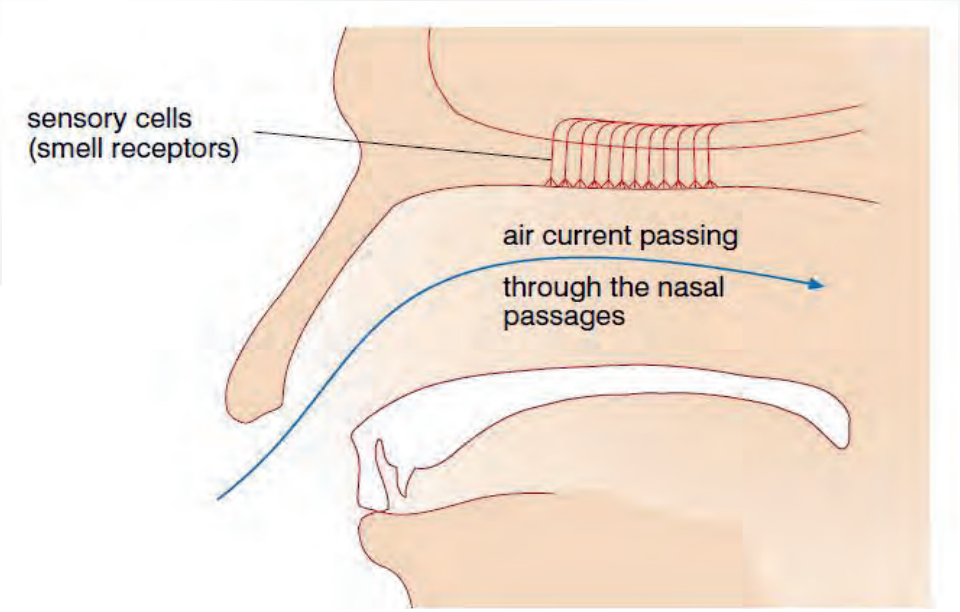


Figure 5.23 Internal structure of nose

Activity 5.23

Discuss in group why you cannot 'taste' foods well when catch a common cold.

For human being to be able to taste and smell, chemicals must go into solution in the form of liquid coating the membranes of receptor cells before they can be detected. The major functional difference between the two kinds of receptors is that smell receptors are more specialized for detecting vapors coming to the organism from distant sources. Taste receptors are specialized for detection of chemicals present in the mouth itself. Furthermore, smell receptors are much more sensitive than taste receptors.

5.2.4. The Eye

The eye structure, function, and defects

The eye transmits visual stimuli to the brain for interpretation and thereby functions as **sensory organ** of vision. The eyeball is located in the eye orbit, a round, bony hollow formed by several different bones of the skull. In the orbit, the eye is surrounded by a cushion of fat. The bony orbit and fat cushion protect the eyeball. To perform a thorough assessment of the eye, it is crucial to understand the external structures of the eye, the internal structures of the eye, the

Keyword

Sensory organ an organ that receives and relays information about the body's senses to the brain

visual fields and pathways, and the visual reflexes.

External structures of the eye

The parts of the eye that include the following are visible externally.

The **eyebrows** protect the eyes by preventing perspiration from running down the forehead and into the eyes, causing irritation. They also help shade the eyes from direct sunlight.

The **eyelids (upper and lower)** with their associated lashes are two movable structures composed of skin and two types of muscle: striated and smooth. Their purpose is to protect the eye from foreign bodies and limit the amount of light entering the eye. In addition, they serve to distribute tears that lubricate the surface of the eye (see Figure 5.24). The eyelids join at two points: the lateral (outer) canthus and medial (inner) canthus. The medial canthus contains the puncta, two small openings that allow drainage of tears into the lacrimal system, and the caruncle, a small, fleshy mass that contains sebaceous glands.

The white space between open eyelids is called the palpebral fissure. When closed, the eyelids should touch. When open, the upper lid position should be between the upper margin of the iris and the upper margin of the pupil. **Eyelashes** are projections of stiff hair curving outward along the margins of the eyelids that filter dust and dirt from air entering the eye.

The **conjunctiva is** a thin, transparent, continuous membrane that is divided into two portions: a palpebral and a bulbar portion. The palpebral conjunctiva lines the inside of the eyelids, and the bulbar conjunctiva covers most of the anterior eye, merging with the cornea at the limbus. This transparent membrane allows for inspection of underlying tissue and serves to protect the eye from foreign bodies.

The **lacrimal apparatus** consists of glands and ducts that serve to lubricate the eye (Figure 5.22). The lacrimal gland, that is located in the upper outer corner of the orbital cavity just above the eye, produces tears. The **extraocular muscles** are the six muscles attached to the outer surface of each eyeball (Figure 15.25). These muscles control six different directions of eye movement. Four rectus muscles are responsible for straight movement,

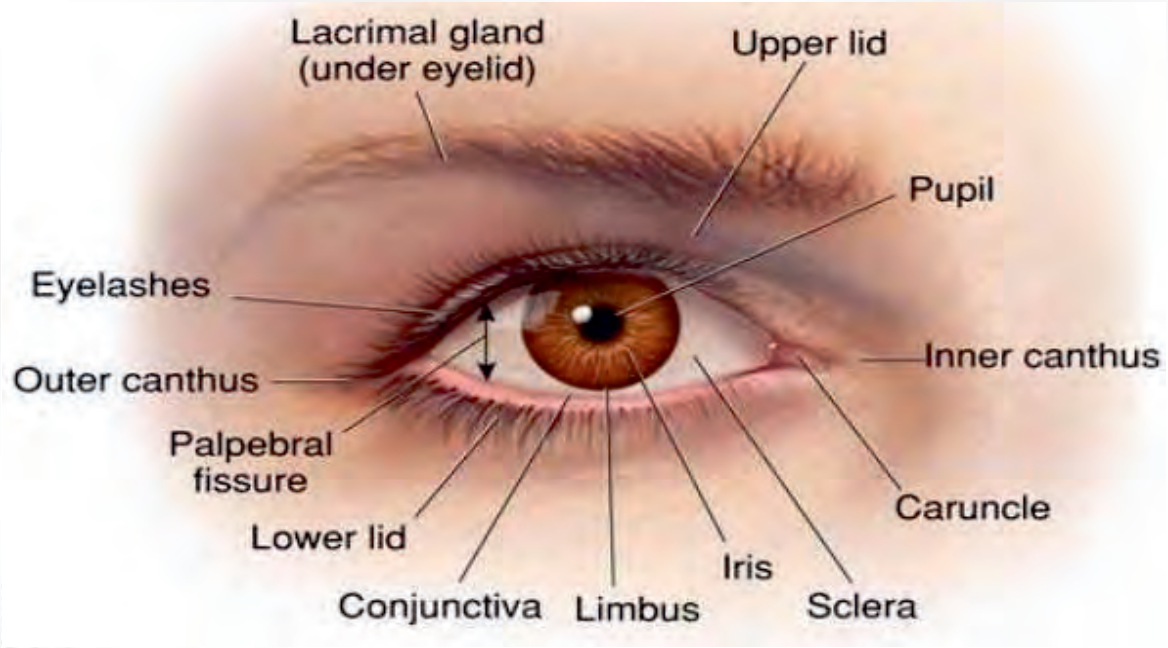


Figure 5.24 External structures of the eye

- and two oblique muscles are responsible for diagonal movement. The **cornea** is the transparent, anterior or front part of our eye, which covers the pupil and the iris. The main function is to refract the light along with the lens. The cornea permits the entrance of light, which passes through the lens to the retina. It is well supplied with nerve endings, making it responsive to pain and touch.
- **Iris:** It is the pigmented, colored portion of the eye, visible externally. The main function of the iris is to control the diameter of the pupil according to the light source.
- **Pupil:** It is the small aperture located in the centre of the Iris. It allows light to enter and focus on the retina.

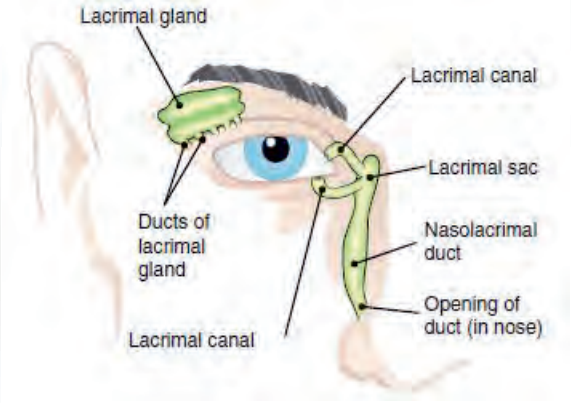


Figure 5.25 Lacrimal apparatus in the human eye

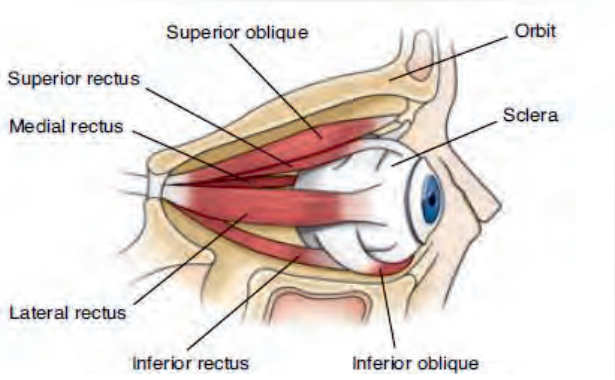


Figure 5.26 Extraocular muscles of the human eye.

Internal structure of the eye

The eyeball is composed of three separate coats or layers (Figure 5.27). The external layer consists of the **sclera** and **cornea**.

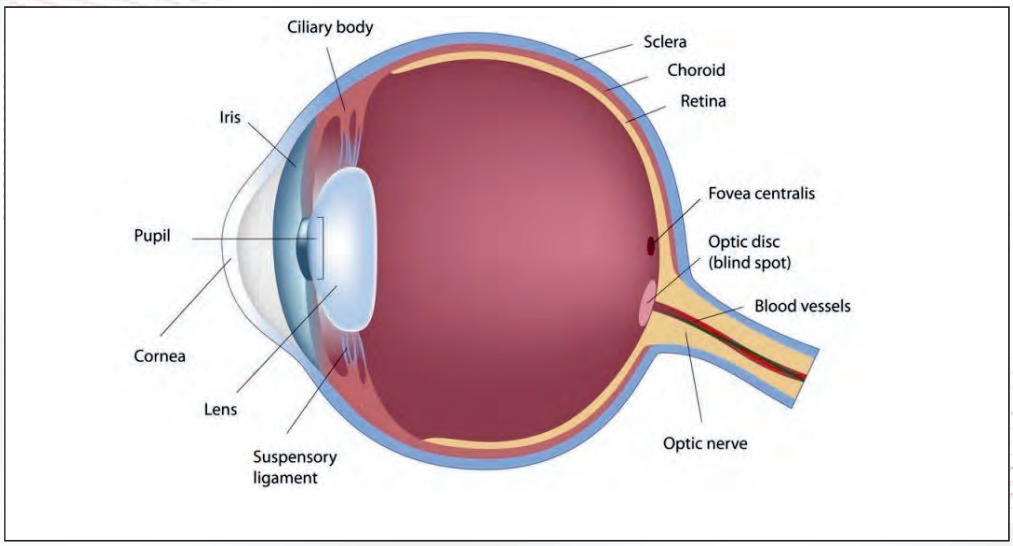


Figure 5.27 Anatomy of the human eye

- The **sclera** is a white visible portion. It is a dense, protective, white covering that physically supports the internal structures of the eye. It is continuous interiorly with the transparent cornea (the "window of the eye").

Activity 5. 24

Understanding the structure of the human eye

In this investigation you are going to look at eyes – your own and one from another animal

You will need:

• A mirror

• A white tile

• Sharp dissecting scissors

• Fresh eye of a sheep, cow or other mammal

Method

1. Look at your eyes in a mirror. How many of the features shown in Figure 5.16 can you see? Draw and label your eyes.
2. Move your eyes from side to side or up and down to see the whites of your eyes which part of the eye is this?
3. Look at the animal's eye provided by your teacher. Draw the external appearance of this eye and label it clearly. Can you see any of the muscles that are used to move the eyeball in the socket?
4. Using your scissors CAREFULLY cut a hole in the side of the eyeball. What comes out? How does this affect the eyeball?
5. Open the eyeball up more fully. Find the lens, the retina and as many other features. NB you won't be able to see them all.
6. Draw and label what you can see once you have opened the eyeball up fully.

The **lens** is a biconvex, transparent, avascular, encapsulated structure located immediately posterior to the iris. **Suspensory ligaments** attached to the **ciliary muscles** support the position of the lens. The lens functions to refract (bend) light rays onto the

Keywords

Lens a flexible disc that helps focus light on the retina

Suspensory ligaments elastic-like structures that suspend the lens and pull it into shape for focusing distant objects onto the retina

Ciliary muscles eye muscles that automatically contract or relax the shape of the lens of the eye to help focus light on the retina

Sclera the tough, opaque tissue that serves as the eye's protective outer layer

Cornea transparent structure over the front of the eye that allows light to enter. A cornea resembles a contact lens in size and appearance

Choroid the middle layer filled with blood vessels that nourish the retina

Pupil a hole in the centre of the iris that changes size in response to changes in lighting

Iris a membrane in the eye, responsible for controlling the amount of light reaching the retina

Dilated becomes wider

Constricted becomes smaller

retina. Adjustments must be made in refraction depending on the distance of the object being viewed. The refractive ability of the lens can be changed by a change in the shape of the lens (which is controlled by the ciliary body). The lens bulges to focus on close objects and flattens to focus on far objects. The **choroid layer** contains the vascularity necessary to provide nourishment to the inner part of the eye and prevents light from reflecting internally. Anteriorly, it is continuous with the ciliary body and the iris. Once the light has travelled through the cornea it has to pass through the **pupil** in the center of the **iris**. The iris is the colored part of the eye, but it is not there simply to look pretty. The iris is made up of muscles that contract or relax to control the size of the pupil and to control the amount of light reaching the retina. The circular muscles run around the iris, whereas the radial muscles run across it like the spokes of a bicycle wheel. When the light is relatively dim, the radial muscles contract and the circular muscles relax and the pupil is pulled open

wide (it **dilates**). When the pupil is dilated, lots of light can get into the eye that enable us to see even in relatively low light conditions. In bright light, however, the circular muscles of the iris contract and the radial muscles relax, which makes the pupil very small (it **constricts**). This reduces the amount of light that goes into the eye so that the delicate light-sensitive cells are not damaged by too much bright light (see Figure 5.28).

The innermost layer, the **retina,** extends only to the ciliary body anteriorly. It receives visual stimuli and sends it to the brain. The retina consists of numerous layers of nerve cells, including the cells commonly called **rods** and **cones**. These specialized nerve cells are often referred to as "**photoreceptors**" because they are responsive to light. The rods are highly sensitive to light, regulate black and white vision, and function in dim light. The cones function in bright light and are sensitive to color. The **optic disc** is a cream-colored, circular area located on the retina toward the medial or nasal side of the eye. It is where the optic nerve enters the eyeball. The optic disc can be seen with

Keyword

Retina a light-sensitive tissue lining the inner surface of the eye

Rods cells in the retina that perceive light and movement and work well in dim light

Cones cells in the retina that perceive light and movement and only work in bright light

Activity 5.25

You can observe the way the size of the pupil changes in response to light in two simple ways – either work with a partner or use a mirror and observe your own eyes.

1. Observe the size of your partner's/your own pupils in the normal working light of your classroom.

2. Cover your eyes with your hands, or with a piece of cloth, for a minute or so – but keep your eyes open normally (you can blink).

3. Remove the cover from the eyes and observe the pupils closely. Note down what you see both immediately after removing the cover and as the eye adjusts to normal light levels (diagrams may help).

4. Now increase the light intensity – move outside into the sunlight or just move nearer to the windows. Again watch and record what happens to the pupils in the brighter light – and when you return to normal classroom levels of light.

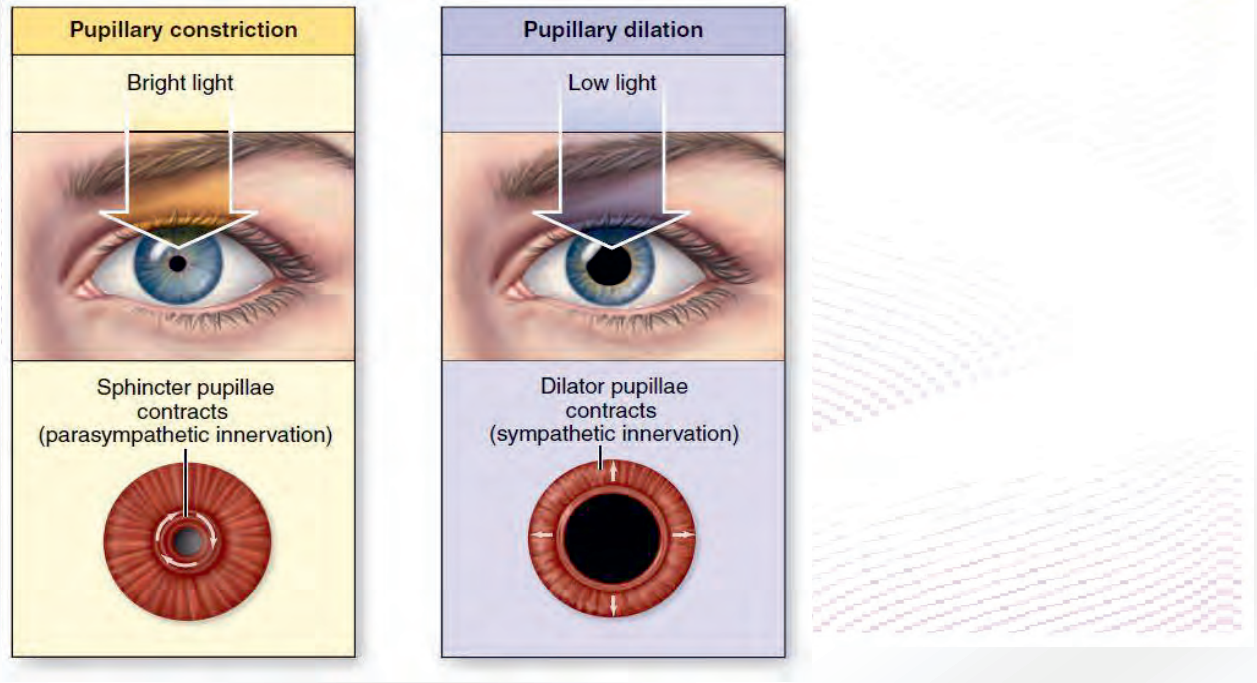


Figure 5.28 Figure showing the constriction and relaxation of pupil

When an image is produced on the retina, the light-sensitive cells are stimulated. They send impulses to the brain along affector (sensory) neurons in the optic nerve. When the brain

receives these messages it interprets the information and enable the person to see. At the point where your optic nerve leaves the eye there is no retina but there is a **blind spot**.

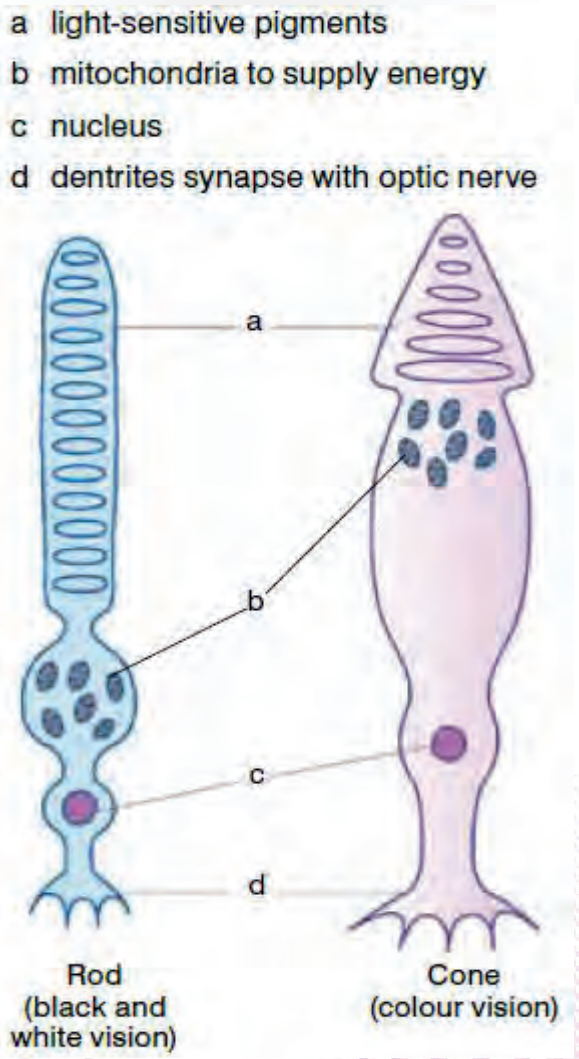


Figure 5.29 The rods and the cones in the retina of human eye


Activity 5.26

1. Look at the picture below. Hold the book so it is 30 cm from your eyes, with the pictures below level with your eyes.

2. Close your left eye completely and focus on the person with your right eye.

3. SLOW LY bring the book towards your face, keeping your right eye focused on the person all the time.

4. What happens to the lion as you move the picture towards you? How do you explain what happens?

5. What happens if you repeat the investigation with both eyes open? Explain any differences you observe.

A retinal depression known as the **fovea centralis** (see Figure 5.29) is located adjacent to the optic disc (blind spot) in the temporal section of the fundus. This area is surrounded by the macula, which appears darker than the rest of the fundus. The fovea centralis and macular area are highly concentrated with cones and form the area of highest visual resolution and color vision. The eyeball contains several chambers that serve to

maintain structure, protect against injury, and transmit light rays. The **anterior chamber** is located between the cornea and iris, and the **posterior chamber** is the area between the iris and the lens (see Figure 5.29). These chambers are filled with aqueous humour, a clear liquid substance produced by the ciliary body. **Aqueous humour** helps to cleanse and nourish the cornea and lens as well as maintain intraocular pressure. The aqueous humour filters out of the eye from the posterior to the anterior chamber then into the *canal of Schlemm* through a filtering site called the *trabecular meshwork.*

Another chamber, the **vitreous chamber,** is located in the area behind the lens to the retina. It is the largest of the chambers and is filled with a clear and gelatinous vitreous humour.

Activity 5.27

Discuss in group and reflect your answer for the following questions.

1. What retina is and how it works.

2. What is color blindness? What do you think is the cause of color blindness?

Activity 5.28 Bending light rays

For this investigation you will need to raid the stores of the physics department.

You will need:

• Light boxes or small, bright light sources

• Lenses

Method

Switch on the light box and observe the light emerging. Try putting the different lenses in the light and make drawings to show how they affect the light rays.

Activity 5. 29 studying refraction

This is a very simple exercise to remind you of the way light can be refracted as it changes medium.

You will need:

• A beaker or glass of water

• A glass rod, ruler or your finger

Method

Look carefully at your rod, ruler or finger. Then dip it into the water in the beaker or glass and observe what appears to happen. Any changes you see are due to the rays of light bending as they pass from water to air.

5.2.5. The Ear

The structure, function, and defects of the ear

Ears are specialized organs for hearing. They are also concerned with the balance and position of the body. The ear is divided into three regions: **the outer ear, middle ear and inner ear**. The outer ear consists of a flap called a **pinna (auricle)**. Leading from the pinna is a tube, the **ear canal**. In a human being, this is about 2 cm long. The pinna helps to trap and funnel sound into the ear. This is particularly important in animals, which can move the pinna to pick up sounds with longer ears than humans. At the end of the ear canal that closes the tube is a sheet of very thin membrane called the **eardrum** or **tympanum**

Activity 5.30

Search from different books and other sources about the different types of human eye defects and how these defects can be resolved? Report your finding to the class.

Activity 5. 31

Make a small group and read from different sources about **cataract** and **glaucoma**. Then, interview health professionals in your locality to obtain additional information about how serious the problem is in your area. Write a report of your finding and present to the class**.**

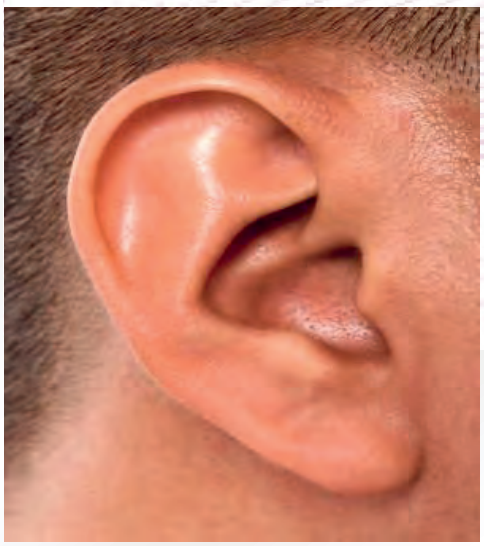


Figure 5.30 The pinna of human ear

Keywords

Outer ear the part of the ear visible externally

Middle ear the main cavity of the ear, between the eardrum and the inner ear

Inner ear a complex system of interconnecting cavities, concerned with hearing and equilibrium

Eardrum the membrane in the ear that vibrates to sound

The pinna, ear canal and the eardrum form the outer part of the human ear. At the entrance of the ear canal are a number of small hairs. These filter out dust particles from the air entering the ear canal. The cells lining the ear canal produce waxy material which traps dust and germs, and lubricates the eardrum.

Behind the eardrum is a cavity filled with air. This cavity contains three tiny bones and forms the middle ear. The three tiny bones– called the **malleus** (**hammer**), the **incus** (**anvil**) and the **stapes** (**stirrup**) (see Figure 5.31) are the smallest bones in the human body. They form joints with one another, with the malleus attached to the eardrum and the stapes to the oval window. The cavity of the middle ear is connected to the throat by a tube called the Eustachian tube. This is usually closed but when the pressure in the middle ear increases, the tube opens until the air pressure in the middle ear is equal to that in the throat and therefore to the atmosphere. At one end of the middle ear, opposite to the eardrum, there are two openings: one of them is oval in shape and hence it is called the oval window. The other is round and is called the round window. The openings are covered by very thin membranes.

The inner ear consists of a cavity filled with a fluid, two sac-like structures called the sacculus and utriculus, three semicircular canals and a coiled tube called the cochlea. The sacculus, utriculus, semicircular canals and the cochlea are filled with a liquid. A cross section of the cochlea reveals that it is made up of three tubes in one (Figure 5.31). The floor of the middle tube is lined with sensory cells linked to affector neurons. These nerve fibers join to form the auditory nerve which leads to the brain.

Keywords

Malleus **(hammer)** *is the ossicle attached to the eardrum*

Incus (anvil) is the ossicle between the malleus and the stapes

Stapes (stirrup) is the stirrup-shaped ossicle that transmits sound from the incus to the cochlea

Ampullae is the e swelling at the base of each semicircular canal, containing sensory cells which detect movement of the fluid within the canals

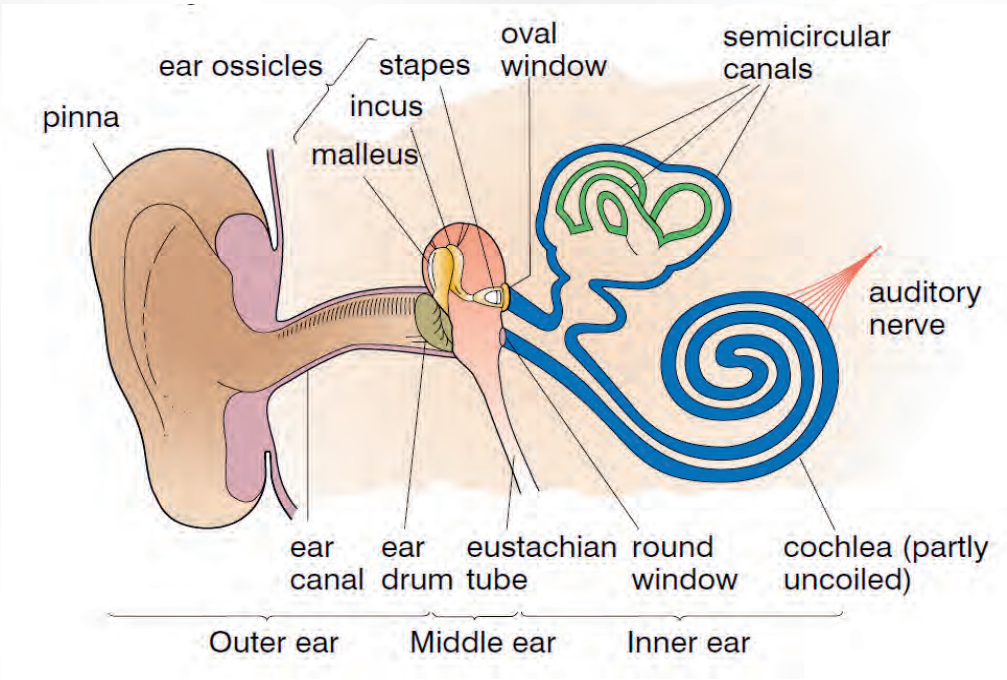


Figure 5.31 Structure of human ear

Activity 5.32

Examination of the human ear

You will need:

- A model of a mammalian ear.

Method

1. Examine the external part of the ear of your classmate. Note its shape and texture.
2. Examine a model of a mammalian ear. Note the shape of the various parts (external and internal parts).
3. Make a drawing of the model.
4. Compare your diagram with that in Figure 5.31

The mechanism of hearing

The pinna collects sound waves and directs them to the eardrum through the ear canal.

When sound waves hit the eardrum, it vibrates. This magnifies the vibrations which are then transmitted through the ear ossicles (the small bones) to the oval window. The ear ossicles also amplify the vibrations (make them bigger).

The vibrations of the stapes make the membrane at the Vibrations of the fluid cause the hair-like sensory cells to move. These movements in turn cause production of nerve impulses in the affector nerve fibres. These impulses are transmitted to the brain for interpretation.

The human ear is sensitive to vibrations ranging from those of a very low note of about 20 vibrations per second, to a very high note of about 30 000 vibrations per second. High notes are detected in the first part of the cochlea and low notes are recorded in the last part of the cochlea.

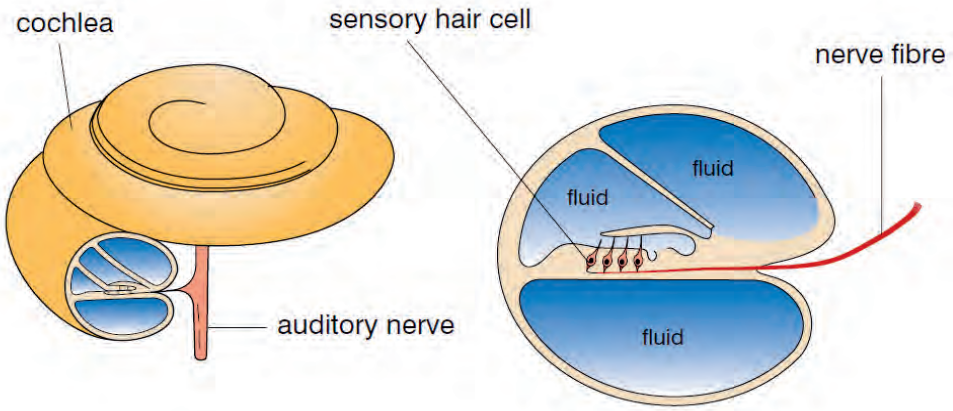


Figure 5.32 The cross section of a cochlea

The sense of balance and movement

The semicircular canals in the inner ear are concerned with the detection of motion. The swellings on each of the semicircular canals (the ampullae) contain sensory cells attached to the sensory nerve endings. The **sensory cells** have hairs which are enclosed in a core of jelly substance called a cupula (Figure 5.32). Whenever the body or the head moves, the semicircular canals move with the head.

The fluid in the semicircular canals also starts to move but it lags behind in its motion, so it apparently moves in the opposite direction. The moving fluid causes the cupula to tilt, thus pressing the hairs of the sensory cells. The pressing of the sensory hairs creates nerve impulses in the sensory nerve endings. The nerve impulses are transmitted to the brain. The brain then interprets the direction and speed of the motion of the body or head.

The semicircular canals are all at right angles to each other, so each one is sensitive to movement in a different plane. One canal responds to nodding, one to shaking and one to head tilting. Fast spinning of the body followed by instant interruption causes dizziness. This is because the fluid in the semicircular canals keeps on moving after the spinning has stopped

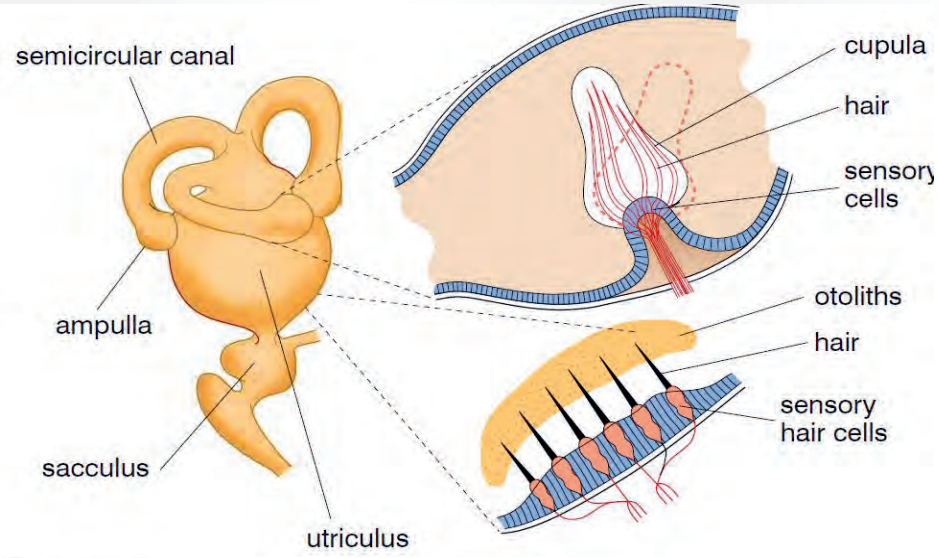


Figure 5.33 The balance organs of the ear

Activity 5.33

Organize yourself to form a small group and search for different materials (books, internet) to understand the possible causes of deafness (hearing loss). The, reflect your finding to the class.

5.2.6. The endocrine system

By the end of this section, the learner will be able to:

- Define glands and hormones
- Identify the location and function of principal endocrine glands, including pituitary thyroid, parathyroid, adrenal, and pancreas
- Compare and contrast exocrine and endocrine glands
- Explain the function of glands and hormones

The endocrine glands

The endocrine system is a diverse collection of cells, tissues, and organs including specialized endocrine glands that produce and secrete hormones, chemical messengers that regulate many physiological processes. The endocrine system has two main components: glands and hormones. An **endocrine gland** consists of cells that produce and secrete hormones into the bloodstream, which carries the secretions throughout the body. A hormone is a regulatory chemical that is secreted into the blood by an endocrine gland or an organ of the body exhibiting an endocrine function. The blood carries the hormone to every cell in the body, but only the target cells for a given hormone can respond to it

The endocrine system interacts with the nervous system to coordinate and integrate body activities by means of **hormones**. Endocrine tissues and organs secrete **hormone** into the body fluids (mainly blood and lymph) directly using diffusion. **Hormones** act as chemical messages that are produced in one part of the body, but they have an effect somewhere entirely different. Glands are structures which produce hormones and other useful substances.

Self- questioning

What are the communication methods used by the endocrine system?

What are the functions of hormones?

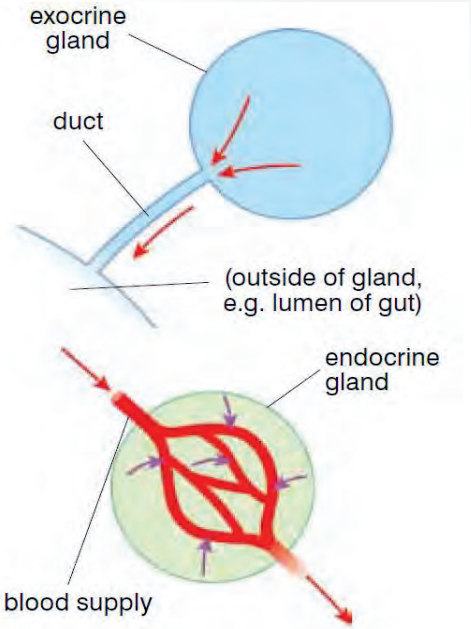
What are the difference between exocrine and endocrine glands?

The **endocrine glands** that produce hormones have no ducts, so they are sometimes known as ductless glands. They secrete hormones directly into the blood, and the chemicals are carried from glands to the body parts throughout the bloodstream.

Most hormones only affect certain tissues or organs – their target organ and the hormone is picked up from the blood by receptors in the cell membranes. They can act very rapidly, but often their effects are slower and longer lasting than the results of nervous control.

In human body there are also glands that produce other substances (not hormones)

released through ducts. These glands are known as **exocrine glands**. **Exocrine glands** are glands which release their cellular secretions through a duct or tube. These include certain sweat glands, salivary and pancreatic glands, sebaceous, and mammary glands. These glands are not considered as a part of the endocrine system.



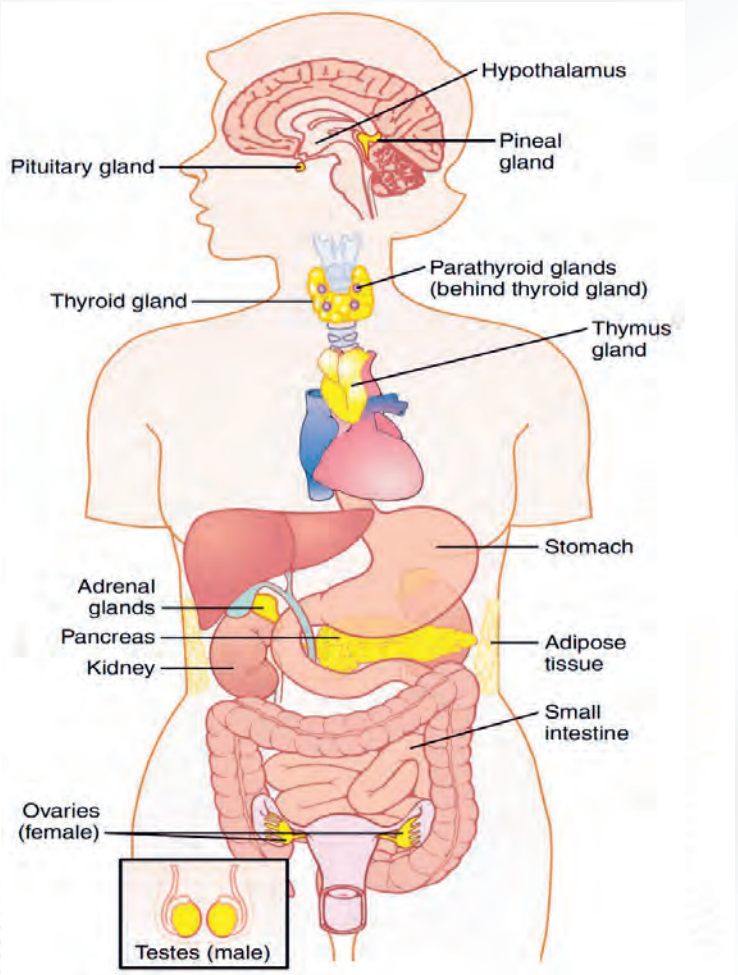


Figure 5.34 Figure showing differences between exocrine gland and endocrine gland, and their secretions.

The major endocrine glands

Figure 5.35 The location of endocrine glands in human body.

Hypothalamus

The hypothalamus connects the nervous system to the endocrine system. It receives and processes signals from other brain regions and pathways where the hypothalamus translates them into hormones that are the chemical messengers of the endocrine system. These hormones flow to the pituitary gland, by the infundibulum. Some hormones are stored in the pituitary stores for later release; others spur it to secrete its own hormones. The hormones are released

by the pituitary gland whereas the hypothalamus controls the other endocrine glands and regulate all the major internal functions.

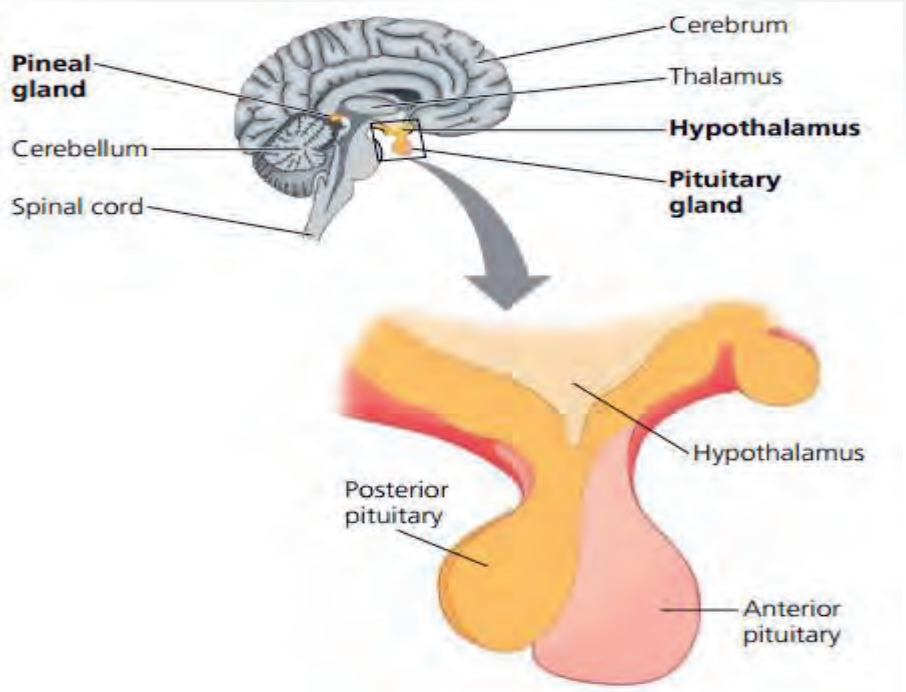


Figure 5.36 Hypothalamus and pituitary gland

The pituitary gland

The pituitary gland, found in the brain and about the size of a pea, is sometimes described as the controller of the endocrine orchestra (master gland). The hormones made in this tiny gland control the secretion of many other hormones. Because of its position in the brain, it is also involved in the co-ordination between the nervous and hormonal systems of control. It is divided into anterior lobe (adenohypophysis) and posterior lobe (neurohypophysis). Anterior lobe is about 3 times larger than the posterior lobe.

A). Anterior pituitary gland

The anterior pituitary makes peptide hormones whose secretion is regulated by the hypothalamus. Most hypothalamic hormones that target cells of the anterior pituitary are releasing hormones, which encourage secretion of hormones. The hypothalamus also makes inhibiting hormones that slow secretion of anterior pituitary hormones. Six major peptide hormones plus several other hormones of lesser importance are secreted by the anterior pituitary. The hormones of the anterior pituitary play major roles in the

control of metabolic functions throughout the body.

• **Growth hormone (GH)**:- promotes growth of the entire body by affecting protein formation, cell multiplication, and cell differentiation. Growth hormone is produced by the anterior pituitary. The quantity is greatest during childhood and adolescence, when most body growth is occurring. If too little GH is produced during childhood, the individual has pituitary **dwarfism**, characterized by perfect proportions but small stature. If too much GH is secreted, gigantism may result. Individuals with gigantism often have additional health problems, primarily because GH has a secondary effect on the blood sugar level, promoting an illness called diabetes mellitus. On occasion, GH is overproduced in the adult and a condition called acromegaly results. Long bone growth is no longer possible in adults, so only the feet, hands, and face (particularly the chin, nose, and eyebrow ridges) can respond, and these portions of the body become overly large.

• **Adrenocorticotropin (corticotropin):-** controls the secretion of some of the adrenocortical hormones, which affect metabolism of glucose, proteins, and fats.

• **Thyroid-stimulating hormone (thyrotropin):-** controls the secretion rate of thyroxine and triiodothyronine by the thyroid gland, and these hormones control the rates of most intracellular chemical reactions in the body.

• **Prolactin**:-is an anterior pituitary hormone that stimulates milk production in a woman's breasts after she gives birth. Shortly after a baby begins to suckle, prolactin binds to receptors on the milk-producing cells of the breasts. The receptors' affinity for prolactin depends on whether the breast is full or empty, enabling the mother's body to adjust the rate of milk production according to the baby's needs.

• Two separate gonadotropic hormones, follicle stimulating hormone and luteinizing hormone, control growth of the ovaries and testes, as well as their hormonal and reproductive activities.

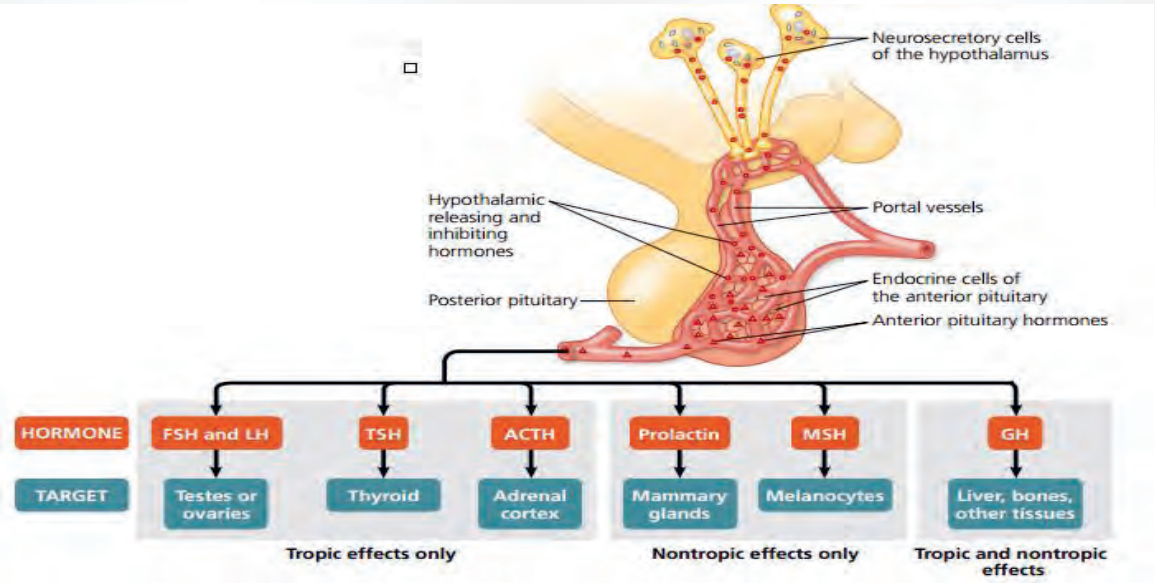


Figure 5.37 hormones secreted by anterior pituitary gland

B). Posterior pituitary gland

The posterior pituitary gland stores and releases hormones when needed that are actually produced by the hypothalamus. These two hormones of the posterior pituitary gland are actually produced by the hypothalamus and simply stored in the posterior pituitary until needed.

These hormones are:

• **Antidiuretic hormone** (also called vasopressin) controls the rate of water excretion into the urine, thus helping to control the concentration of water in the body fluids.
• **Oxytocin** helps express milk from the glands of the breast to the nipples during suckling and helps in the delivery of the baby at the end of gestation.

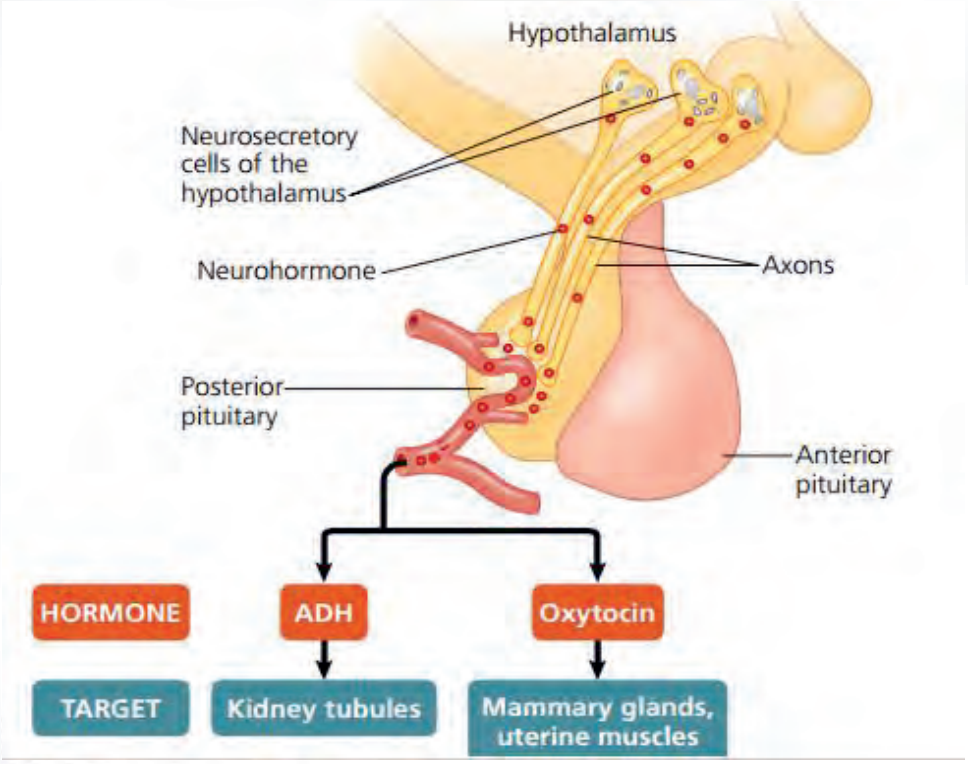


Figure 5.38 Hormones secreted by hypothalamus and stored in the posterior pituitary gland

Table 5.2 Hormones of the posterior pituitary gland

Hormone	Functions	Regulation of secretion
Antidiuretic hormone (ADH or vasopressin)	Increases water reabsorption by the kidney tubules (water returns to the blood) • Decreases sweating • Causes vasoconstriction (in large amounts)	Decreased water content in the body (alcohol inhibits secretion)
Oxytocin	Promotes contraction of myometrium of uterus (labor) • Promotes release of milk from mammary glands	Nerve impulses from hypothalamus, the result of stretching of cervix or stimulation of nipple Secretion from placenta at end of gestation—stimulus unknown

Activity 5.34

Search from different books and other sources about the different types of hormones produced (released) by the anterior pituitary and posterior pituitary gland. List down some of the problems associated with these hormones. Report your finding to the class.

Thyroid gland

The thyroid gland (Greek thyros ,"shield") is a small, butterfly-shaped gland located inferior to the larynx (voice box) and attached to the trachea. It is divided into two lateral lobes. Thyroid follicles utilize iodine and synthesize **thyroglobulin (TGB)** to be stored in the colloids. Upon stimulation of thyroid-stimulating hormone (TSH), TGB is converted into two hormones: **Triiodothyronine (T3)** and **Thyroxine (T4)** to promote normal metabolism. Hypo secretion causes hypothyroidism (goiter, cretinism and myxedema) and hyper secretion causes hyperthyroidism that result in Graves' disease. Thyroid gland also secretes Calcitonin to lower blood calcium and phosphate levels and regulate digestive hormones. Both hypo secretion and hyper secretion would affect the normal balances of calcium and phosphate.

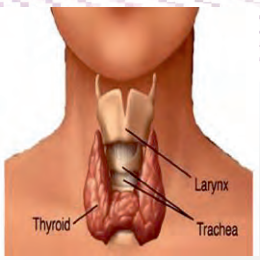


Figure 5.39 The thyroid gland

Activity 5.35

Search from different sources (books and the internet) and rea about:

1. The function of thyroxine
2. The current situation of goiter cases in Ethiopia?
3. Why women and children are more affected by iodine deficiency than men?
4. If there is a solution for most of the problems of iodine deficiency disorders? Reflect your findings to the class.

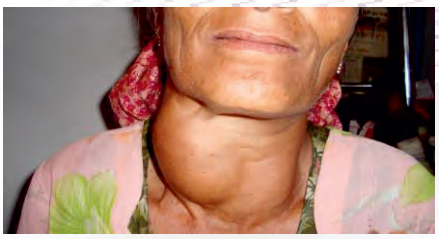


Figure 5. 40 A woman with goiter

Malfunction of the thyroid gland leads to specific disorders

Extreme hypothyroidism during infancy and childhood results in low metabolic rate and can lead to **cretinism,** a condition characterized by retarded mental and physical development. When diagnosed early enough, hypothyroidism can be treated with thyroid hormones, and cretinism can be prevented. An adult who feels like sleeping all the time, has little energy, and is mentally slow or confused may be suffering from hypothyroidism.

High levels of TSH stimulate the thyroid gland, whose cells enlarge in a futile attempt to manufacture more thyroxine. Without iodine, the thyroid gland keeps getting bigger and bigger - a condition known as a **goiter**. In most countries, goiter is prevented through the addition of iodine to table salt.

Parathyroid glands

Four oval-shaped glands are embedded in the posterior surface (back) of the thyroid gland. Each parathyroid gland is normally about the size of a grain of rice (about 3-5 millimeters in diameter and 30 - 60 milligrams in weight). Parathyroid glands release **parathyroid hormone (PTH)** which controls the calcium levels in the blood stream. Other areas of the body, especially the bones, kidneys and small intestine, respond to PTH by increasing the calcium levels in the blood. Calcium is very important for our bodies, especially for muscle and nerve function. Hypo secretion causes tetany, and hyper secretion causes osteitis fibrosa cystica.

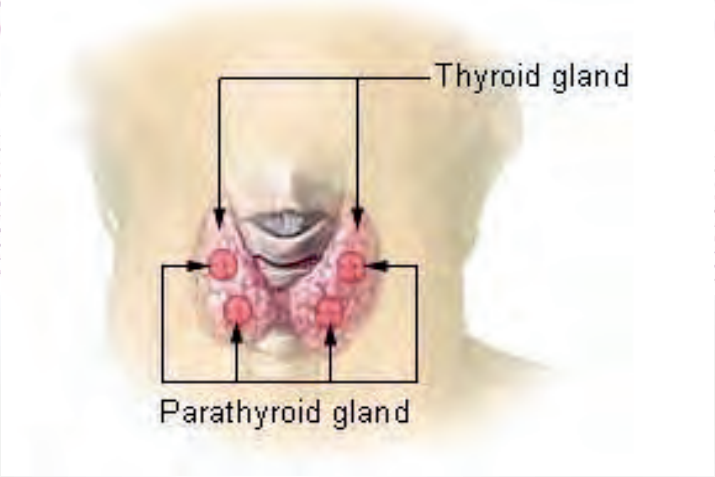


Figure 5.41 Parathyroid gland

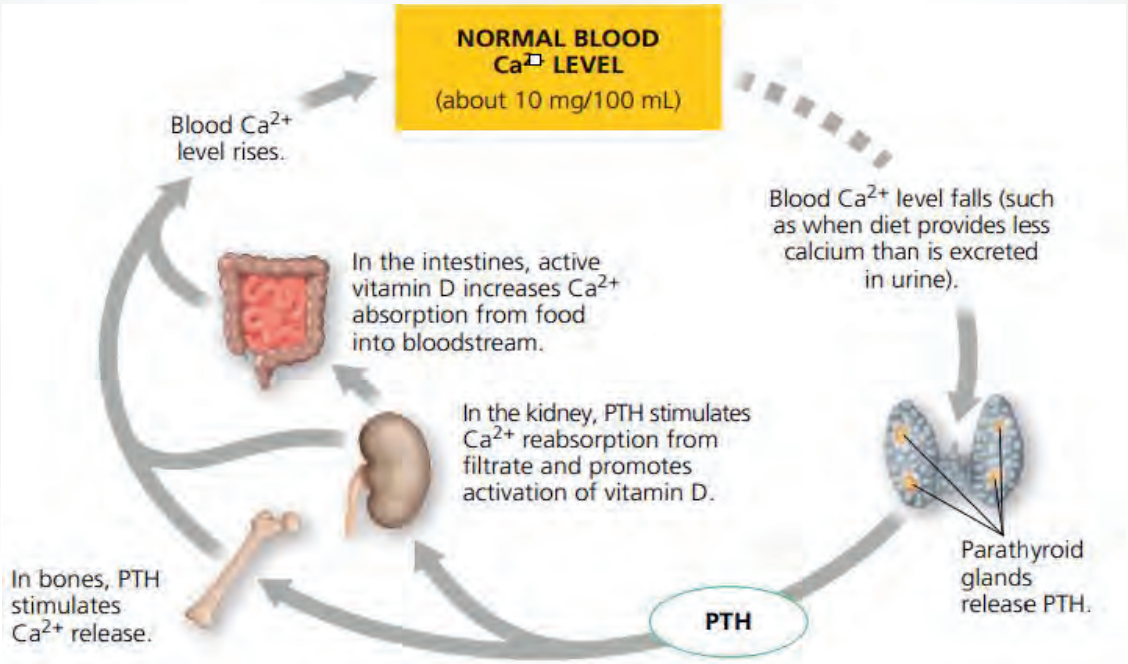


Figure. 5.42 The function of PTH in the regulation of blood calcium levels in mammals

Adrenal glands

Adrenal glands, also known as suprarenal glands, are small, triangular-shaped glands located on the top of both kidneys. Adrenal glands are composed of two parts. The cortex and the medulla-which are responsible for the production of different hormones.

A. Adrenal Cortex: is the outer portion of the adrenal gland which is attached to the superior surface of the kidney. It is divided into 3 regions, from outside to inside: **Zona glomerulosa**, **Zona fasciculate** and **Zona reticularis**. Adrenal cortex secretes over 30 steroid-based substances and several steroid hormones, all crucial for normal homeostasis.

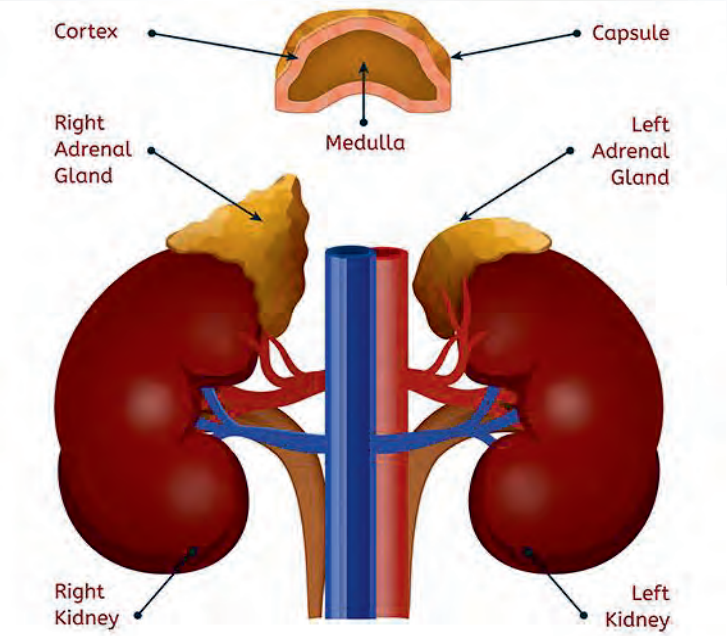


Figure 5.43 Adrenal glands

Activity 5.36

Search from different sources and read about the types of hormones secreted by Zona glomerulosa, Zona fasciculate and Zona reticularis and the role of each hormone. Also, find some of the problems associated with hyper secretion or hypo secretion of each hormone. Discuss your finding in the class.

B. Adrenal Medulla: This is the inner portion of the adrenal gland. It is made of modified nerve tissue that is under direct regulation of sympathetic nerves of the autonomic nervous system. Contains glandular cells called chromaffin cells which secrete 2 closely related hormones- **Epinephrine (adrenaline)** and **Norepinephrine (noradrenaline).**

Adrenaline is a well-known hormone produced by your adrenal glands. It is the hormone of 'fight or flight'. If you are stressed, angry, excited or frightened your adrenal glands will secrete lots of adrenalin. Carried rapidly round in your blood, adrenalin affects many different organs from the pupils of your eyes (it dilates them) to the *beating of your heart (it speeds it up).* Adrenalin basically prepares

Activity 5.37

Discuss in group the role of adrenaline.

your body for action, so that you can run fast to escape or fight successfully if you need to.

Table 5.3 Hormones of adrenal glands

Hormone	**Functions**	**Regulation of secretions**
Norepinephrine	Causes vasoconstriction in skin, viscera, and skeletal muscles	
Epinephrine/ Adrenalin	• Increases heart rate and force of contraction • Dilates bronchioles • Decreases peristalsis • Increases conversion of glycogen to glucose in the liver • Causes vasodilation in skeletal muscles • Causes vasoconstriction in skin and viscera • Increases use of fats for energy • Increases the rate of cell respiration	Sympathetic impulses from the hypothalamus in stress situations
Aldosterone	Increases reabsorption of Na ions by the kidneys to the blood • Increases excretion of K ions by the kidneys in urine	Low blood Na+ level Low blood volume or blood pressure High blood K level
Glucocorticoid hormones (cortisol (hydrocortisone), cortisone and corticosterone)	The glucocorticoid hormones have several effects: • they influence the metabolism of most body cells; • they promote glycogen storage in the liver; • during fasting they stimulate the generation of glucose; • they increase blood glucose levels; • they are involved in providing resistance to	ACTH (anterior pituitary) during physiological stress

Hormone	Functions	Regulation of secretions
	stressors; • they decrease the permeability of vascular endothelium; • they promote the repair of damaged tissues by promoting the breakdown of stored protein to create amino acids; • they suppress the immune system; • they suppress inflammatory processes.	

Pancreas

Pancreas is a small pink organ found below the stomach. It is both exocrine and endocrine in physiology. In its exocrine aspect, 99% of its mass is composed of cells called acini which secrete digestive enzymes and fluids into the small intestine through the pancreatic ducts. In its endocrine aspect, 1% of its mass is little groups of cells called **islets of langerhans (or pancreatic islets)** secrete hormones to regulate blood glucose level. In each pancreatic islet, **alpha cells (α cells)** secrete **glucagons** to raise blood glucose level, **beta cells (β cells)** secrete **insulin** to lower blood glucose level. Hypo secretion causes **diabetes mellitus** and hyper secretion causes **hyperinsulinism**. **Delta cells (δ cells)** secrete **somatostation** or **growth hormone inhibiting hormone (GHIH)** which helps regulate carbohydrate metabolism by inhibiting the secretion of glucagons.

Keywords

Pancreas is a gland that produces digestive enzymes and manufactures hormones, including insulin and glucagon

Insulin is a hormone that lowers the blood glucose level

Glucagon is a hormone that raises the blood glucose level

Glycogen is a form of carbohydrate stored primarily in the liver and

Activity 5.38

What are the basic differences between Type I and Type II diabetes? Read from different sources and discuss in the class.

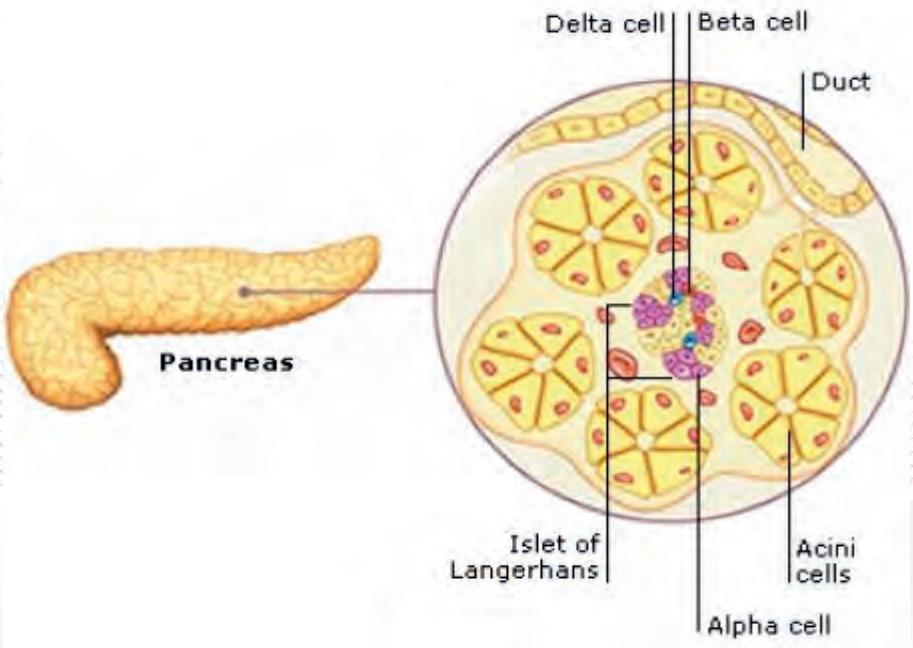


Figure 5.44 Islets of Langerhans in pancreas

A). Insulin

Insulin is well known for its effect in reducing the blood glucose levels. It does this by:

A. It increases conversion of glucose into glycogen and deposition of it in liver and muscles.

B. It increases the rate of oxidation of glucose in the tissues.

C. It increases the rate of conversion of glucose into fat and facilitates its storage in adipose tissue.

D. It also regulates the rate at which amino acids are catabolized into water and CO2.

Types of diabetes

Type 1 diabetes:- in which the pancreas can no longer manufacture insulin, may be the result of an autoimmune reaction that specifically targets the beta cells. Antibodies to specific components of beta cells have been found in the pancreases of Type 1 diabetes patients. Research suggests that hereditary factors may also play a role in the onset of this disease.

Type II diabetes:- is due to insulin resistance. The insulin target cells do not respond normally to the circulating insulin. This may result due to obesity, over-eating and lack of exercise. The insulin hypo responsiveness can be corrected if the person reduces his or her caloric intake. Thus dietary control without any other therapy is frequently sufficient to eliminate the elevated blood glucose level of type II diabetics. An exercise programmed is also useful, since it will help to increase the number of insulin receptors.

B). Glucagon

Glucagon has an important role in maintaining normal blood glucose levels, especially as the brain and neurons can only use glucose as a fuel. Glucagon has the opposite effect on blood glucose levels to insulin it:

- stimulates the breakdown of glycogen stored in the liver;
- activates hepatic gluconeogenesis (the creation of glucose from substrates such as amino acids);
- has a minor effect enhancing triglyceride breakdown in adipose tissue – providing fatty acid fuel for most cells, and thus conserving glucose for the brain and neurons.

The production and secretion of glucagon are stimulated in response to a reduction in blood glucose concentrations and elevated blood levels of amino acids (for instance,

after a protein-rich meal). It has also been found that glucagon levels in the blood rise in response to exercise, but it is unclear whether this is a response to the exercise itself or a response to the reduced blood glucose levels that exercise creates.

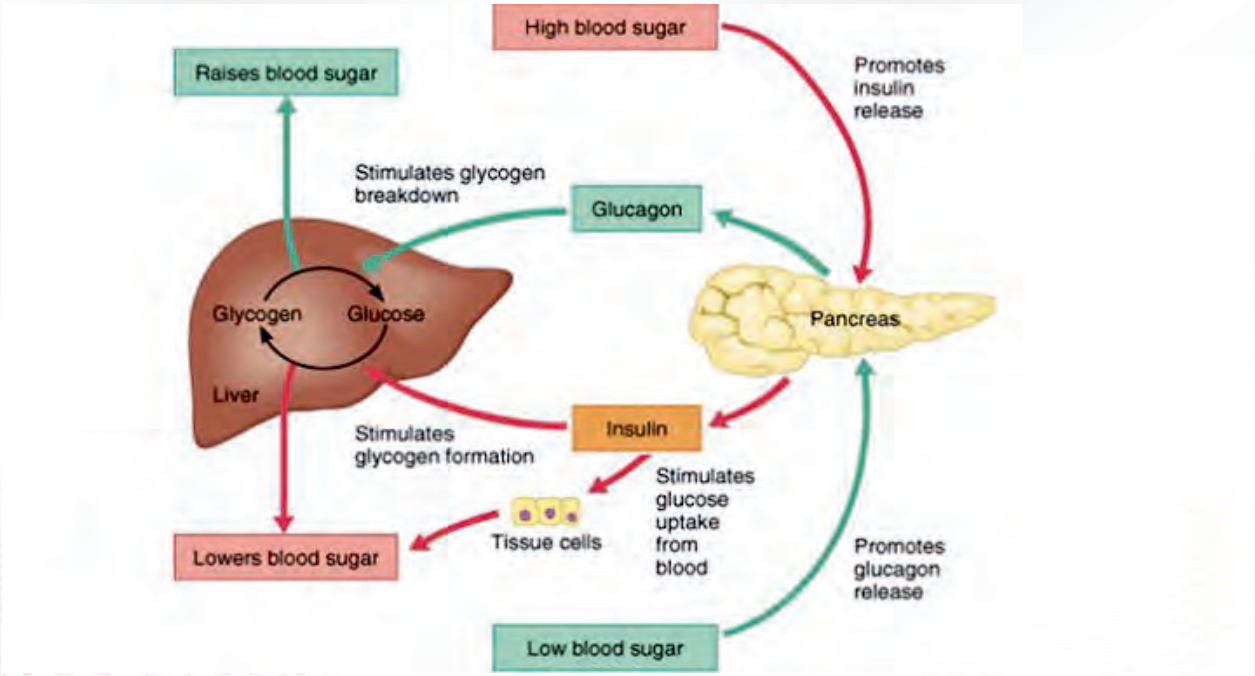


Figure 5. 45 Regulation of blood sugar level

The gonads: Ovary and testis

Self-questioning

Can you explain what causes secondary sexual characteristic in boys and girls?

The **gonads** are the endocrine glands which produce some of the sex hormones. These are the testes in boys and ovaries in girls who become active at the time of puberty. When the big physical changes take place, boys and girls look very different which the body takes its adult form. The changes come about in response to hormones released by the brain and by the gonads themselves.

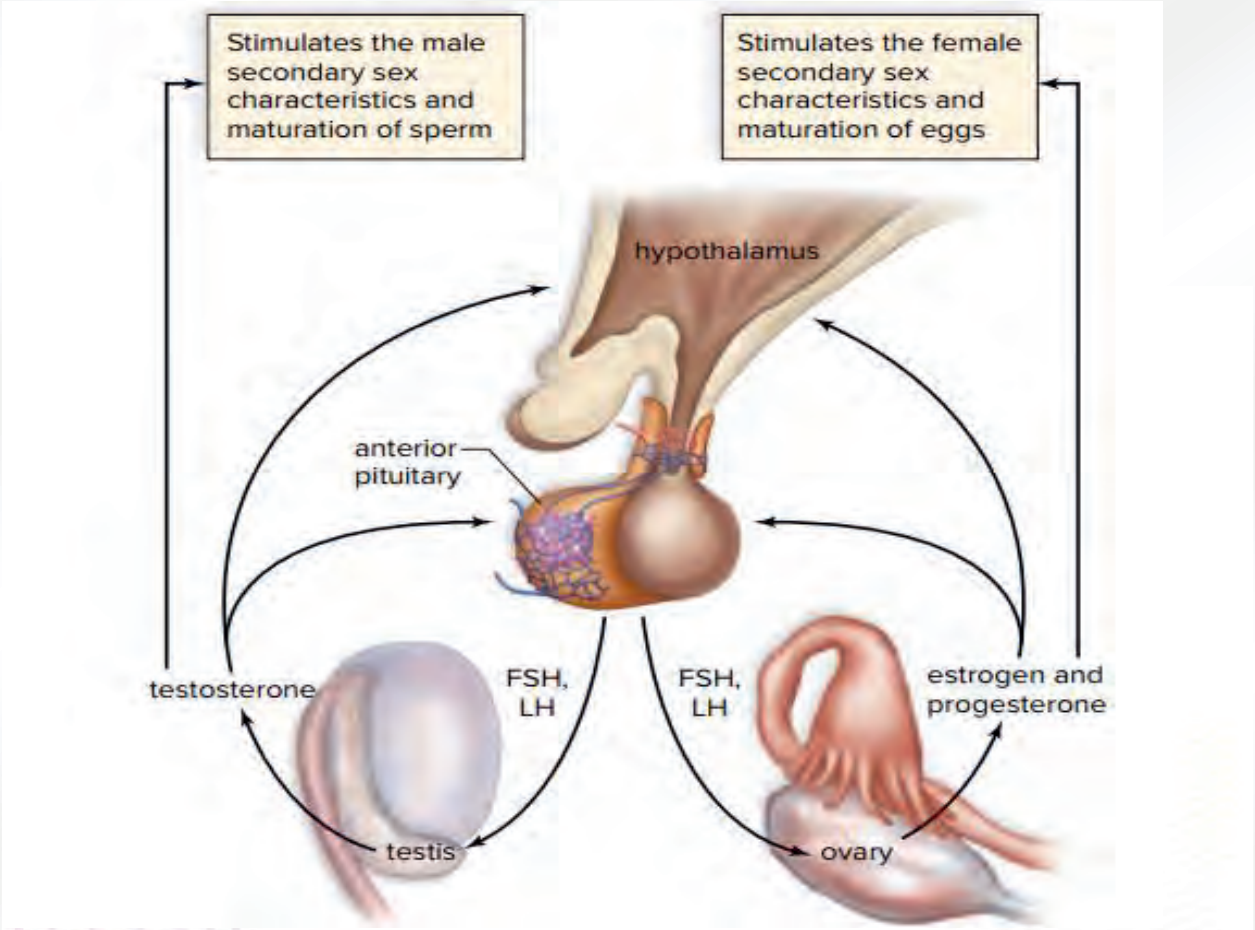


Figure 5.46 The hormones produced by the testes and the ovaries

The role of the ovaries

The female gonads are the ovaries, two walnut-sized organs found low in the abdomen in either side of the uterus. Ovaries produce eggs and hormones. Girls often go into puberty slightly earlier than boys. Between the ages of 8–14 most girls begin the changes which will take their bodies into sexual maturity. As with boys, the time and speed of puberty varies greatly from one person to another. Although it is different for everyone, and everyone ends up a slightly different shape and size – the basic changes which take place are the same.

Puberty in girls is controlled by hormones


Activity 5.39

Search from different books and other sources about the hormones that have effect on the female reproductive system, control of the menstrual cycle and female fertility. Present your work to the class.

from the pituitary gland in the brain and from the gonads themselves – in this case the ovaries. Follicle stimulating hormone (FSH) from the brain stimulates the ovaries to become active and start producing hormones. The hormones produced by the ovaries are the steroids estrogen and progesterone.

Estrogen

Estrogen is secreted by the follicle cells of the ovary; secretion is stimulated by **FSH** from the anterior pituitary gland. Estrogen promotes the maturation of the ovum in the ovarian follicle and stimulates the growth of blood vessels in the endometrium (lining) of the uterus in preparation for a possible fertilized egg.

The **secondary sex characteristics** in women also develop in response to estrogen. These include growth of the duct system of the mammary glands, growth of the uterus, and the deposition of fat subcutaneously in the hips and thighs.

Progesterone

When a mature ovarian follicle releases an ovum, the follicle becomes the **corpus luteum** and begins to secrete **progesterone** in addition to estrogen. This is stimulated by **LH** from the anterior pituitary gland. Progesterone promotes the storage of glycogen and the further growth of blood vessels in the endometrium, which thus becomes a potential placenta. The secretory cells of the mammary glands also develop under the influence of progesterone.

The role of the testes

Testis is the male sex organ that also serves as an endocrine gland. It contains interstital cells (or leydig's cells) that secrete **testosterone** to develop male secondary sexual characteristics. Puberty in boys usually begins somewhere between the ages of 9 and 15 years old. It may happen very rapidly, or it may take place much more slowly over a number of years. Two people do not experience puberty in exactly the same way.

The chemical changes which trigger puberty are unseen, which is another important example of hormonal co-ordination and control. The pituitary gland in the brain starts to produce increasing amounts of **FSH**. This in turn stimulates the male gonads or testes to begin developing and producing the male sex hormone **testosterone**. The rising levels of testosterone trigger the many changes which affect the body during puberty, causing the development of the secondary sexual characteristics.

Source	Ovaries		Testes
Hormone	Progesterone	Estrogen	Testosterone
Type	Steroid	Steroid	Steroid
Target cells	Uterine lining, hypothalamus, pituitary, other tissues	Uterine lining, hypothalamus, pituitary, other tissues	Sperm-producing cells, hypothalamus, pituitary, other tissues
Major responses	Regulates menstrual cycle, prepares body for pregnancy	Regulates menstrual cycle, maintains secondary sex characteristics in females	Promotes sperm development, maintains secondary sex characteristics in males

Figure 5.47 hormones secreted by ovaries and testes

Pineal gland

Pineal gland is pine cone shaped located deep in the cerebrum. It secrets **melatonin** to regulate **circadian rhythms** which are necessary to keep track of day or night cycles, sleep/wake rhythm, menstrual and ovarian cycles.

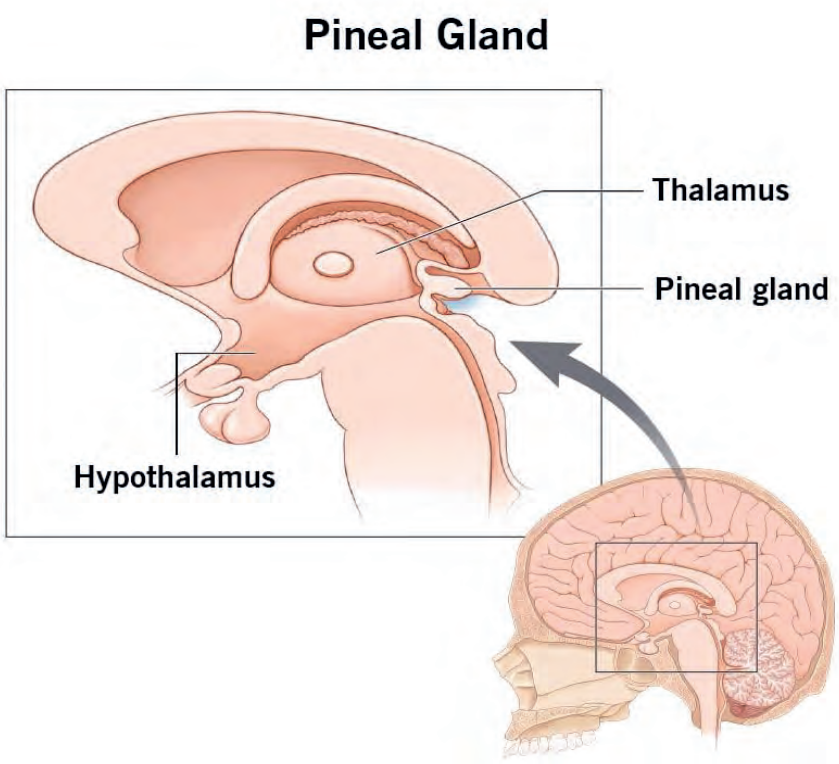


Figure 5.48 Pineal gland

Circadian Rhythms

Melatonin secretion by the pineal gland of the brain plays a pivotal role in the control of circadian rhythms

- Circadian rhythms are the body's physiological responses to the 24 hour day-night cycle
- Circadian rhythms are driven by an internal (endogenous) circadian clock, although they can be modulated by external factors

Melatonin is the hormone responsible for synchronising circadian rhythms and regulates the body's sleep schedule

- Melatonin secretion is suppressed by bright light (principally blue wavelengths) and hence levels increase during the night
- Over a prolonged period, melatonin secretion becomes entrained to anticipate the onset of darkness and the approach of day
- Melatonin functions to promote activity in nocturnal animals and conversely promotes sleep in diurnal animals (like humans)
- During sleep, necessary physiological changes occur in body temperature, brain wave activity and hormonal production

Melatonin levels naturally decrease with age, leading to changes in sleeping patterns in the elderly .

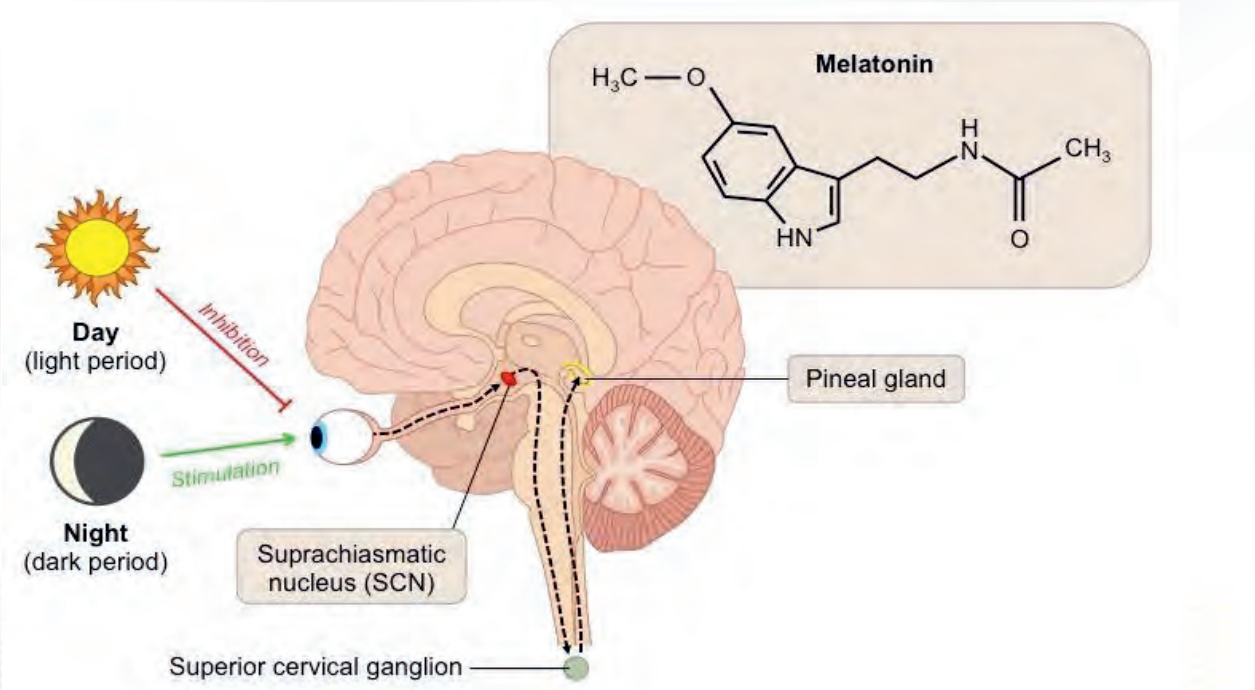


Figure 5.49 Pineal gland

Thymus gland

A thymus gland is a diminishing gland (over time) located between the lungs. It secretes a group of hormones, such as **thymosin**, to affect the production and maturation of lymphocytes in body defenses.

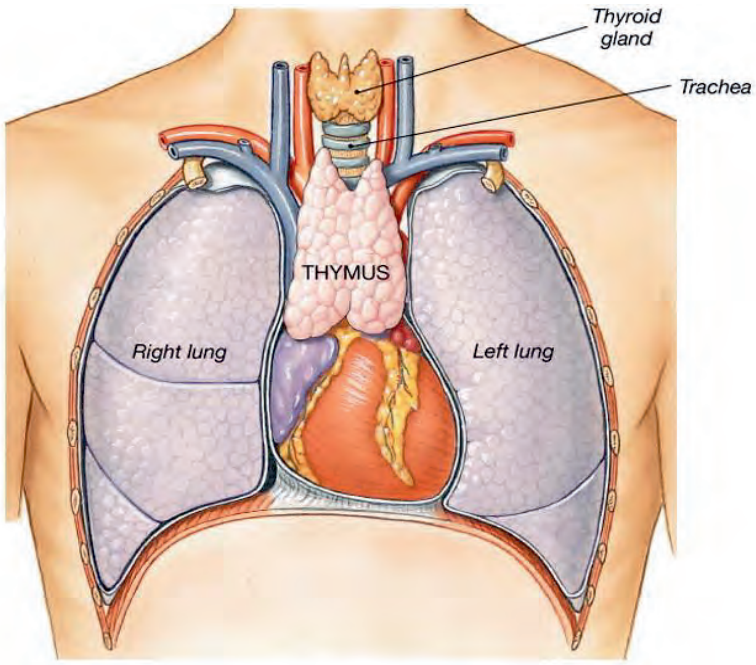


Figure 5.50 Thymus gland

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Activity 5.40

Discuss in group the difference between endocrine and exocrine glands and reflect your views to the class.

5.3. Homeostasis in the human body

At the end of this section, the learner will be able to:

- Define homeostasis
- Explain the regulatory mechanisms of body temperature, sugar level, water balance
- Discuss the structures and functions of the human kidney
- Investigate traditional mechanisms in your locality used to regulate body homeostasis

5.3.1. The structure and function of the human kidney

The kidneys are a pair of bean-shaped organs just above the waist. They are important organs with many functions in your body, including producing hormones, absorbing minerals, and filtering blood and producing urine. Internally, the kidney has three regions: an outer cortex, a medulla in the middle, and the renal pelvis, which is the expanded end of the ureter. The renal cortex contains the nephrons, which is the functional unit of the kidney. The renal pelvis collects the urine and leads to the ureter on the outside of the kidney. The ureters are urine-bearing tubes that exit the kidney and empty into the urinary bladder.

Self-questioning

How do kidneys control the levels of water and ions in the human body?

Blood flows into the kidney along the renal artery. The blood is filtered, so fluid containing water, salt, urea, glucose and many other substances is forced out into the kidney tubules. Then everything the body needs is taken back (reabsorbed), including all of the sugar and the mineral ions needed by the body.

The amount of water reabsorbed depends on the needs of the body. The waste product urea and excess ions and unwanted water of the body are released as urine. Each kidney has a very rich blood supply and is made up of millions of tiny microscopic tubules (nephrons) where all the filtering and reabsorption takes place.

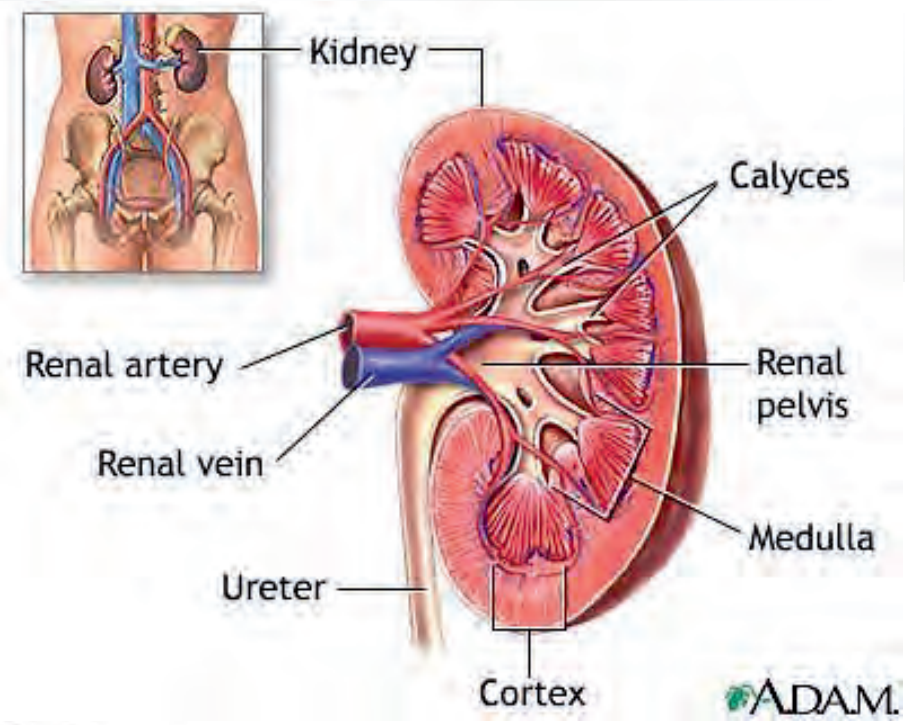


Figure 5.51 The anatomy of human kidneys

The roles of the different areas of a single kidney tubule in the production of urine are described below:

- **Bowman's capsule** is the site of the ultrafiltration of the blood. The blood vessel feeding into the capsule is wider than the vessel leaving the capsule, which means the blood in the capillaries is under a lot of pressure. Several layers of cells, the wall of the blood capillaries and the wall of the capsule act as a filter and the blood cells and the large blood proteins cannot leave the blood vessels as they are too big to fit through the gaps. However, water, salt, glucose, urea and many other substances are forced out into the start of the tubule. In fact, the concentration of substances in the liquid in the capsule is the same as that in the blood itself. This process is known as ultrafiltration – filtration on a very small scale.

- **Glomerulus:** This is the knot of blood vessels in the Bowman's capsule where the pressure builds up so that ultrafiltration occurs. The volume of the blood leaving the glomerulus is about 15% less than the blood coming in which is a measure of the liquid which has moved into the capsule as a result of ultrafiltration.

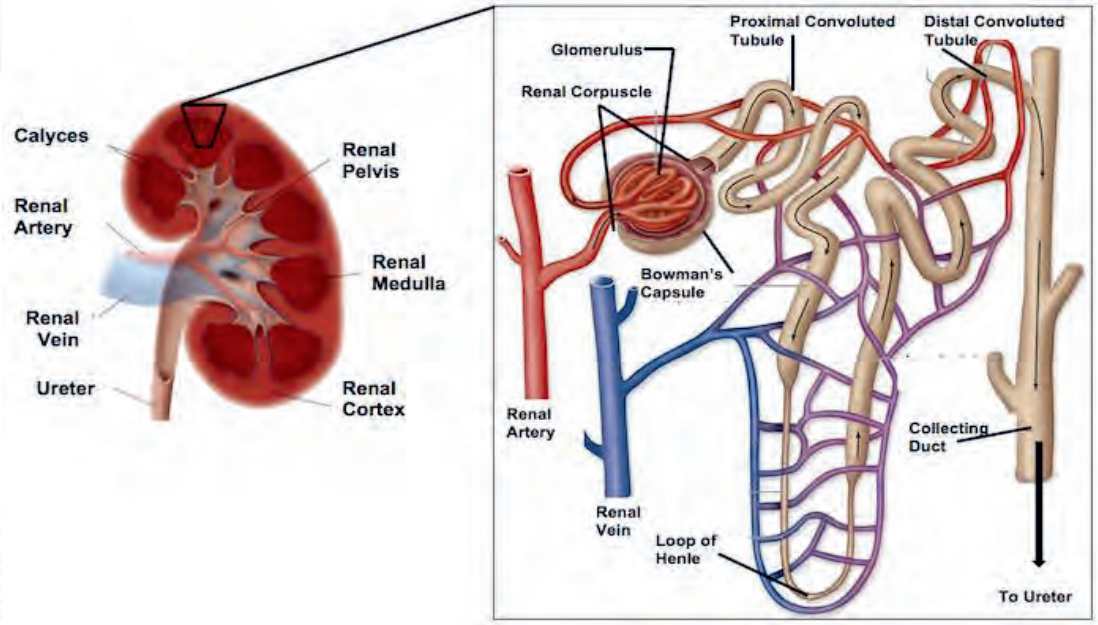


Figure 5.52 The kidney filters the blood and removes waste materials.

- **First coiled (convoluted) tubule:** This is the liquid which enters this first tubule is known as the glomerular filtrate. The first tubule is where much of the reabsorption takes place. All of the glucose is actively taken back into the blood along with around 67% of the sodium ions and around 80% of the water. It has many microvilli to increase the surface area for absorption.
- **Loop of Henlé:** is part of a kidney where the urine is concentrated and more water is conserved.

Second coiled (convoluted) tubule: is part of a kidney where the main water balancing is done. If the body is short of water, more is reabsorbed into the blood in this tubule under the influence of the anti-diuretic hormone or ADH. (Diuresis means passing urine, so anti-diuresis means preventing or reducing urine flow.) Also ammonium ions and some drugs (if they have been taken into the body) are secreted from the blood into this tubule to get rid of them. By the end of this second coiled tubule all of the salt which is needed by your

body has been reabsorbed, leaving the excess in the filtrate along with most of the urea.

- **Collecting duct:** is also part of a kidney where the liquid (essentially urine) is collected. It contains about 1% of the original water, with no glucose at all. The level of salt in the urine will depend on the amount of salt in your diet and the water content of the urine. There is also a much higher concentration of urea (about 60 times more) in the urine than in the blood. But, if your body badly needs more water, more may be reabsorbed along the collecting duct again under the influence of ADH – until the urine passes into the pyramid of the kidney and on into your bladder.

Urine is formed constantly in your kidneys as it drips down to collect in your bladder. The bladder is a muscular sac which can hold between 600 and 800 cm3 urine, although we usually empty it when it contains only 150–300 cm3.

The amount of water lost from the kidney in the urine is controlled by a sensitive feedback mechanism involving the hormone ADH. If the water content of the blood is too low (so the salt concentration of blood increases) special sense organs known as osmoreceptors in the brain detect this. They stimulate the pituitary gland in the brain to release ADH into the blood. This hormone affects the second coiled tubules of the kidneys, making them more permeable so more water is reabsorbed back into the blood.

Activity 5.41

By dissecting a kidney you can see the way the different tissues are arranged. Remember to indicate the magnification of your drawing each time – if it is life size, it is × 1.

You will need:

• Fresh kidney (lamb or sheep) from a butcher house, preferably with the fat surrounding the kidney in place

• Dissecting instruments – a scalpel, forceps and a seeker

• Ddissecting board

Method

1. Observe the outer appearance of the kidney with the fat on, if possible. Draw and label about what you observe.

Activity 5.43

Investigating kidney structure

2. Carefully remove the fat, clearing the tubes leading into and away from the kidney carefully. Again draw and label what you see.

3. Slice the kidney in half longitudinally (along its length) and open it out to see the internal structure. Again draw and label the regions carefully – use Figure 5.43 to help you identify them.

4. You may have the opportunity to look at prepared slides of kidney tissue under the microscope – if so, keep the drawings you make with these drawings from a fresh kidney to build up a record of the whole organ from your own observations.

This means less water is left in the kidney tubules and so a more concentrated urine is formed. At the same time the amount of water in the blood increases so that the concentration of salts in the blood returns to normal.

If the water content of the blood is too high, the pituitary gland releases much less ADH into the blood. The kidney then reabsorbs less water back into the blood, and thereby producing a large volume of dilute urine. Water is effectively lost from

the blood and concentration of salts returns to normal.

This system of osmoregulation is an example of negative feedback. As the water concentration of the blood falls, the level of ADH produced rises. Then as the water concentration of the blood rises again, the level of ADH released falls. On an average day the kidneys will produce around 180 l (that's about 50 gallons) of liquid filtered out of the blood in the glomerulus (glomerular filtrate) – but only about 1.5 l (just over 2.5 pints) of urine. So more than 99% of the liquid filtered out of the blood is eventually returned to it.

Activity 5.42

Discuss in small groups about homeostasis in action by considering the type of urine produced when someone drinks a lot of water and small volume of water?

Thermoregulation

It is vitally important that wherever we go and whatever we do our body temperature is maintained at the temperature (around 37 °C) at which our enzymes work best. It is not the temperature at the surface of an organism which matters as the skin temperature can vary enormously without causing harm. It is the temperature deep inside the body, known as the internal or core body temperature, which must be kept stable. Human beings are good examples of homeotherms. The body temperature is controlled by a number of physiological mechanisms which work together to allow gain or lose heat you need to.

Activity 5. 43

Search for different types of books and read about the different types of physiological and behavioral methods of temperature regulation in the human body. Present your work to the class.

Self-questioning

What types of mechanism do humans do have to regulate their body temperature?

1. Osmoregulation

If the concentration of the body fluids changes, water will move into or out of the cells by osmosis and they could be damaged or destroyed. Yet some days you may drink several liters of water of liquid and other days much less. How is the balance maintained?

We gain water when we drink and eat. We lose water constantly from the lungs when we breathe out, when water evaporates into the air in the lungs and is breathed out. This water loss is constant.

Whenever we exercise or get hot we sweat and lose more water. The water balance is maintained by the kidneys. They remove any excess water which leaves the body as urine. If we are short of water we produce very little urine and most water is saved for use in the body. If we have too much water then our kidneys produce lots of urine to get rid of the excess. The ion concentration of the body – particularly ordinary salt – is also important. We take in mineral ions with our food. Some are lost via our skin when we sweat. Again the kidney is most important organ to keep an ion balance. Excess mineral ions are removed by the kidneys and lost in the urine. The balance of water and salts in the body is very important because of the osmotic impact of the cells. If the balance is wrong controlling this balance is known as **osmoregulation**. The kidneys as discussed above are vitally important in two aspects of homeostasis, both in excretion and in osmoregulation.

2. Chemical regulation

Human liver plays a vital role in maintaining a constant internal environment. It is the largest individual organ in the body that makes up around 5% of the body mass. The liver cells are very active in carrying out a wide range of functions, many of which help to maintain a constant internal environment. The liver has a very special blood supply in addition to the usual artery and vein (hepatic artery and vein) there is another blood vessel which comes to the liver directly from the gut. This is the hepatic portal vein and it brings the products of digestion to the liver to be dealt with.

Activity 5. 44

Discuss in small groups if there are traditional mechanisms used to regulate body homeostasis in your locality.

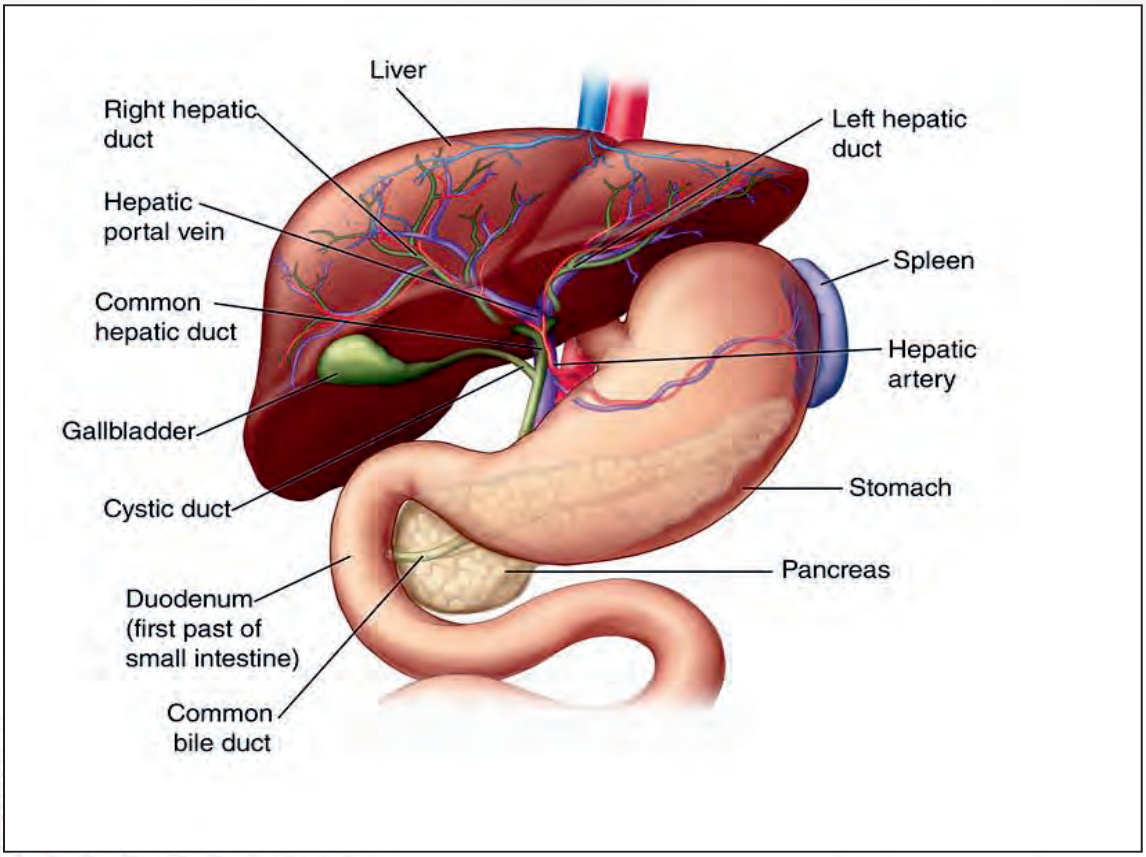


Figure 5.53 The liver is one of the most active organs in the body

A large number of reactions take place in the liver. Many of them are involved in homeostasis in one way or another. It plays a part in all of the following functions:

It controls the sugar levels in the body (through stored glycogen in the liver itself).

It controls and balances the fats that you eat and the cholesterol levels in the blood.

It is an important organ where protein metabolism takes place. The liver breaks down excess amino acids and forms urea. If you eat more carbohydrate or fat than you need in the diet the body simply stores the excess energy as fat. If you eat too much protein, it isn't so easy. The body cannot store the excess amino acids or simply convert protein to fat. Instead the amino acids which make up the protein are broken down in the liver. The amino (nitrogen containing) part of the amino acid molecule is removed and converted into ammonia and then urea in the liver. The rest of the amino acid can be used in cellular respiration or converted to fat for storage. The process of removing the amino group from excess amino acids is known as **deamination.** This it is a very important function of the liver.

It carries out the breakdown of worn-out red blood cells – in particular the red pigment hemoglobin.

It is vital organ for the formation of bile which is made in the liver and stored in the gall bladder before it is released into the gut to emulsify fats and help in their digestion.

It controls toxins. The liver breaks down most of the poisons you take into the body, including alcohol. This is why the liver is so often damaged when people drink heavily.

It is used to control temperature. Around 500 different reactions take place in the liver at any time. For many years it has been believed that as a result of all these reactions the liver generates a lot of heat which is then spread around the body by the bloodstream.

The regulation of tissue oxygenation is another typical example for chemical regulation in the body. The respiratory chemoreceptors work by sensing the pH levels of their environment through the concentration of hydrogen ions. Because most carbon dioxide is converted to carbonic acid (and bicarbonate) in the bloodstream, chemoreceptors are able to use blood pH as a way to measure the carbon dioxide levels of the bloodstream.

The main chemoreceptors involved in respiratory feedback are:

1. Central chemoreceptors: These are located on the ventrolateral surface of medulla oblongata and detect changes in the pH of spinal fluid. They can be desensitized over time from chronic hypoxia (oxygen deficiency) and increased carbon dioxide.
2. Peripheral chemoreceptors: These include the aortic body, which detects changes in blood oxygen and carbon dioxide, but not in the pH, and the carotid body which detects all three. They do not desensitize, but they have less impact on the respiratory rate compared to the central chemoreceptors.

Activity 5.45

Search from different books and materials about other types of chemical regulation that takes place in the human body. Report your finding to the class.

The need for different levels of respiration varies with the physiologic state of the organism (e.g., sleep, excitement, exercise). The respiratory system must try to maintain constant levels of O_2, CO_2 and H^+ in the arterial blood which then ensures relatively constant levels of these important substances in the interstitial fluid. For O_2, one needs an adequate supply to meet cellular metabolic requirements. For CO_2 and H^+, one needs to maintain the acid–base status of the body's cells. The respiratory system provides a

rapid, but usually incomplete, compensation for acid–base disturbances through altered partial pressure of CO2. (PCO2). Changes in the levels of O2, CO2 and H+ in the blood cause compensatory changes in the level of ventilation.

a. The side effects of drugs on the normal functioning of nervous and endocrine systems

Activity 5.46

In this chapter you have learned about the drug abuse and their effect on your body. Now it can be easier for you to further strength your understanding by doing research in this topic.

Make a small group as per the instruction of your teacher and research about the effects of drugs (smoking, alcohol use, chewing khat and cannabis) on the normal functioning of the nervous system and endocrine system. You are advised to prepare a questionnaire and an interview for drug users and health professionals in your locality. Report your findings to the class.

Unit Summary

In this unit you have learnt human beings have both nervous and hormonal co-ordination and control systems. The nervous system is the most rapid. A nerve cell or neuron consists of a cell body, dendrites and an axon. Sensory neurons carry information from the sense organs to the central nervous system (CNS). Motor neurons carry instructions from the CNS to the effector organs (muscles and glands). Neurons carry electrical impulses known as the action potential.

In any pathway the junctions between neurons are called synapses. When an impulse arrives in one neuron chemicals are released in the synapse to trigger an impulse in the next neuron. Nerve contains many neurons. There are sensory nerves, motor nerves and mixed nerves. The spinal cord carries information from all over the body to and from the brain. Cranial nerves come from the brain, while spinal nerves are from the spinal cord.

Reflex actions avoid danger without conscious thought. Reflex actions involve: stimulus → receptor → co-ordinator →effector → response but the co-ordinator is the relay neuron in the spinal cord and there is no conscious thought involved. The knee jerk reflex is a common example of a reflex. Drug abuse is when someone use a substance to the point of excess and/or dependence. Drug dependence is when an individual use a drug again and again and become addicted.

Drugs change the chemical processes in human body then become addicted to them. Alcohol, tobacco and khat are the widely used substances in Ethiopia.

Sense organs detect changes in the internal or external environment. The human eye includes: sclera, cornea, iris, pupil, lens, ciliary muscle, suspensory ligament, retina and optic nerve. The light-sensitive cells the rods and the cones are found in the retina. The iris controls the amount of light entering the eye. The cornea bends the light into the eye. The lens controls the fine focus of the image onto the retina. Short sight, long sight and astigmatism are three common defects of the eye. The ear is an organ of hearing and of balance. Hearing involves the outer, middle and inner ear. Balance involves the semicircular canals.

Chemical co-ordination and control of the body is brought about by hormones secreted by special endocrine glands. The hormones are secreted directly into the blood and are carried around the body in the blood. They may affect a single target organ or a range of organs and tissues. They have their effect through special receptor molecules on the cell membranes of the target organs and tissues. Hormonal

control may be rapid but is often relatively slow and long term. Important endocrine organs include the pituitary gland, the thyroid gland, the adrenal glands, the pancreas, the ovaries and the testes. Insulin produced by the pancreas controls the blood sugar levels Hormones from the pituitary and the ovary control the menstrual cycle.

Unit review questions

Choose the correct answer for the following questions.

1. The two types of main components of macromolecules in myelin are;
   a. carbohydrates and lipids
   b. proteins and nucleic acids
   c. lipids and proteins
   d. carbohydrates and nucleic acids
2. If a thermoreceptor is sensitive to temperature sensations, what would a chemoreceptor be sensitive to?
   a. Light
   b. Sound
   c. Molecules
   d. vibration
3. What ion enters a neuron causing depolarization of the cell membrane?
   a. Sodium
   b. Chloride
   c. Potassium
   d. phosphate
4. Which of the following response is not part of the fight-or-flight response?
   a. pupil dilation
   b. increased oxygen supply to the lungs
   c. suppressed digestion
   d. reduced mental activity
5. Which one of the following correctly traces the transmission of sound from the external environment to the nerves that carry the signal to the brain to be interpreted?
   a. Cochlea, tympanic membrane, ossicles, pinna, external auditory meatus.
   b. Pinna, external auditory meatus, tympanic membrane, ossicles, cochlea
   c. Tympanic membrane, Cochlea, ossicles, pinna, external auditory meatus
   d. External auditory meatus, Pinna, tympanic membrane, ossicles, cochlea

6. Which structure detect rotational acceleration of the head and body?

a. Ossicles

b. Cochlea

c. Tympanic membrane

d. Semicircular canals

7. Which section of the ear contains the malleus, incus, and stapes bones?

a. Outer ear

b. Middle ear

c. Inner ear

d. Pinna

8. Which of the following is not an example of homeostasis?

a. control of the blood sugar levels

b. control of the body temperature

c. control of the water content of the blood

d. control of the length of the limbs

9. Which of the following areas is NOT part of the nephron (kidney tubule)?

a. Bowman's capsule

b. urinary bladder

c. loop of Henle

d. first coiled tubule

10. Which of the following is not part of the eye?

a. lens

b. retina

c. pinna

d. eyelid

11. Imagine you have been out on the beach looking at some friends in the sea. You walk into the shade of a palm tree and begin to read a book. What changes would take place in your eyes?

a. Your pupils would constrict and your lens would become flatter and less convex.

a. Your pupils would constrict and your lens would become rounder and more convex.

b. Your pupils would dilate and your lens would become flatter and less convex.

c. Your pupils would dilate and your lens would become rounder and more convex.

12. Which is the correct order of the bones in the middle ear, from the eardrum inwards?

a. hammer, anvil, stirrup

b. anvil, hammer, stirrup

c. stirrup, anvil, hammer

d. none of these

13. Which is the most recently discovered sense of taste?

a. sweet

b. bitter

c. sour

d. umami

14. Which of the following endocrine glands secretes a hormone that directly affects the metabolic rate of the body?

a. pituitary gland b. ovary

c. thyroid d. pancreas

14. Which of the following reproductive hormones is produced by the pituitary gland?

a. oestrogen
b. testosterone
c. follicle stimulating hormone
d. progesterone

15. Which of the following is not an example of homeostasis?

a. control of the blood sugar levels

b. control of the body temperature

c. control of the water content of the blood

d. control of the length of the limbs

16. Which of the following areas is NOT part of the nephron (kidney tubule)?

a. Bowman's capsule
b. urinary bladder
c. loop of Henle
d. first coiled tubule

b. Which of the following statements is true about ADH?

17. ADH is a hormone produced in the brain which affects the second coiled tubules of the kidneys, making them more permeable so more water is reabsorbed back into the blood and little, concentrated urine is formed.

a. ADH is a hormone produced in the brain which affects the first coiled tubules of the kidneys, making them more permeable so more water is reabsorbed back into the blood.

b. ADH is a hormone produced in the kidney which affects the coiled tubules of the kidneys, making them more permeable so more water is reabsorbed back into the blood.

c. ADH is a hormone produced in the brain which affects the second coiled tubules of the kidneys, making them less permeable so less water is reabsorbed back

Provide correct answer for the following questions

1) Explain the role of neurotransmitters.

2) Compare and contrast endocrine and exocrine glands

3) Briefly explain the coordination of the body by means of hormones and electrical impulses.

4) Describe the role of negative feedback in the function of the parathyroid gland.

5) Describe the antagonistic actions of insulin and glucagon

6) Describe the role of some of the pigments that are found in your skin

7) What are the three regions of the adrenal cortex and what hormones do they produce?

8) List down the hormones produced by anterior pituitary gland.

9) Describe the role of negative feedback in the function of the thyroid gland.

10) Explain some of the eye disorders with their possible corrections.

11) Briefly explain how you can use your ears to hear a sound

12) Why is the pituitary gland considered as a master gland?

13) How does the hypothalamus interact with the posterior and anterior pituitary glands?

14) Describe the functions of the hormones released by the posterior and anterior pituitary glands.

15) Compare the hormones of the adrenal cortex and medulla

Unit 6: Climate Change

Unit 6: Climate Change

At the end of this unit, the learner will be able to:

- Explore the key scientific concepts of climate change.
- Analyze the causes of climate change and how human activities affect the climate.
- Discuss the effects of climate change on living things
- Elaborate the measures to combat climate change

Keyword

Climate change is a long-term change in the earth's climate, especially a change due to an increase in the average atmospheric temperature.

6.1. Climate Change: Causes and effects

6.1.1. Definition of Climate Change

Climate change is the global phenomenon of climate transformation characterized by the changes in the usual climate of the planet (temperature, precipitation, and wind) that are especially caused by human activities. Climate change is a systematic change in the long-term state of the atmosphere over multiple decades or longer.

6.1.2. Causes of climate change

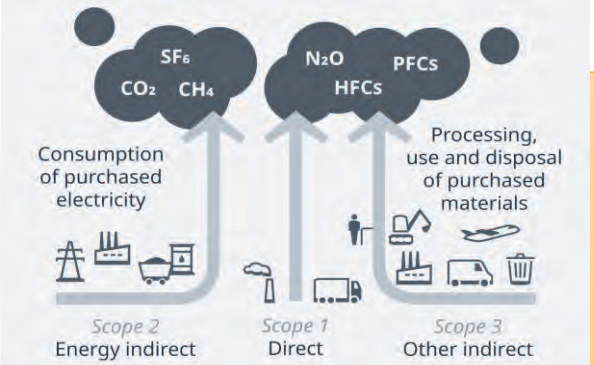
What Causes Climate change?

Activity 6.1

Make a small group and discuss about weather, climate, climate variability and climate change. Reflect your answer to the class.

Humans are increasingly influencing the climate and the earth's temperature by burning fossil fuels, cutting down forests and farming livestock that increases the concentration of atmospheric CO2 by more than 40%, with over half the increase occurring since 1970.. This adds enormous amounts of greenhouse gases to the atmosphere, increasing the greenhouse effect and global warming. At its most basic, climate change is caused by a change in the earth's energy balance how much of the energy from the sun that enters the earth (and its atmosphere) is released back into space. The earth is gaining energy as we reduce the

Greenhouse gases are released into the atmosphere at various scopes (Figure 6.1) that have an influence on the earth's energy balance by trapping heat in the atmosphere, which makes the Earth



Natural and anthropogenic substances and processes that alter the Earth's energy budget are drivers of climate change.

amount of solar energy that is reflected out to space.

What are greenhouse gases?

Greenhouse effect

Greenhouse gases (GHGs) are gases in the earth's atmosphere that trap heat. Water vapour, Carbon dioxide (CO2), methane and nitrous oxide are the major GHGs. During the day, the sun shines through the atmosphere and warms the earth's surface. At night the earth's surface cools, releasing heat back into the air. During this time some of the heat is trapped by the greenhouse gases in the atmosphere and keeps the earth's temperature at an average 14˚C (57˚F). The gases act like glass walls of a greenhouse and hence the name, greenhouse gases. Without this greenhouse effect, temperatures would drop to as low as -18˚C (-0.4˚F); too cold to sustain life on earth.

warmer. In Earth's atmosphere like carbon dioxide, methane, nitrous oxide and Hydrofluorocarbons (HFCs) act as a **greenhouse**, preventing a certain amount of heat radiation from escaping back to space.

Figure 6.1. Source–Path relationship of Greenhouse gases

Since the Industrial Revolution, human activities have added very large quantities of greenhouse gases into Earth's atmosphere. These GHGs act like a blanket or car windshield to trap the sun's energy and heat, rather than letting it reflect back into space. When the concentration of GHGs is too high, too much heat is trapped, and the earth's temperature rises outside the range of natural variability. There are many GHGs, each with a different ability to trap heat and a different half-life in the atmosphere. GHGs are sometimes called "climate active pollutants" because most have additional notable effects on human health.

Table 6.1. Types of greenhouse gases and their major sources

GHG Categories	Major Sources
Carbodioxide (CO_2)	Fossil Fuel Combustion, deforestation
Methane (CH_4)	Landfills, Rice paddies, Digestive tracts of cattle and sheep
Nitrous Oxide (N_2O)	Fertilizer, animal waste
Hydrofluorocarbons (HFCs)	Semiconductor manufacturing and other industrial processes
Perfluorocarbons (PFCs)	Same as HFCs, plus aluminum smelting
Sulfur hexafluoride (SF_6)	Electrical transmission systems, magnesium and aluminum production

Carbon dioxide (CO_2) is the GHG responsible for greatest amount of warming to date. The majority of CO_2 is released from the incomplete combustion of fossil fuels-coal, oil, and gas used for electricity production, transportation and industrial processes (Table 6.1).

Carbon dioxide absorbs and radiates heat warmed by sunlight, and thermal infrared energy (heat). Unlike oxygen or nitrogen

Self-questioning

- What is the difference between global warming and climate change?
- Is the sun a major driver of recent changes in climate?
- What happens to carbon dioxide after it is emitted into the atmosphere?

which make up most of our atmosphere, GHGs absorb that heat and release it gradually over time and trap additional heat and raise Earth's average temperature.

Carbon dioxide is one of the most important elements of the earth's long-lived greenhouse gases. It absorbs less heat per molecule than methane or nitrous oxide, but it's more abundant and stays in the atmosphere much longer. Increases in atmospheric carbon dioxide are responsible for about two-thirds of the total energy imbalance that is causing the earth's temperature to rise (see Figure 6.2 and Figure 6.3).

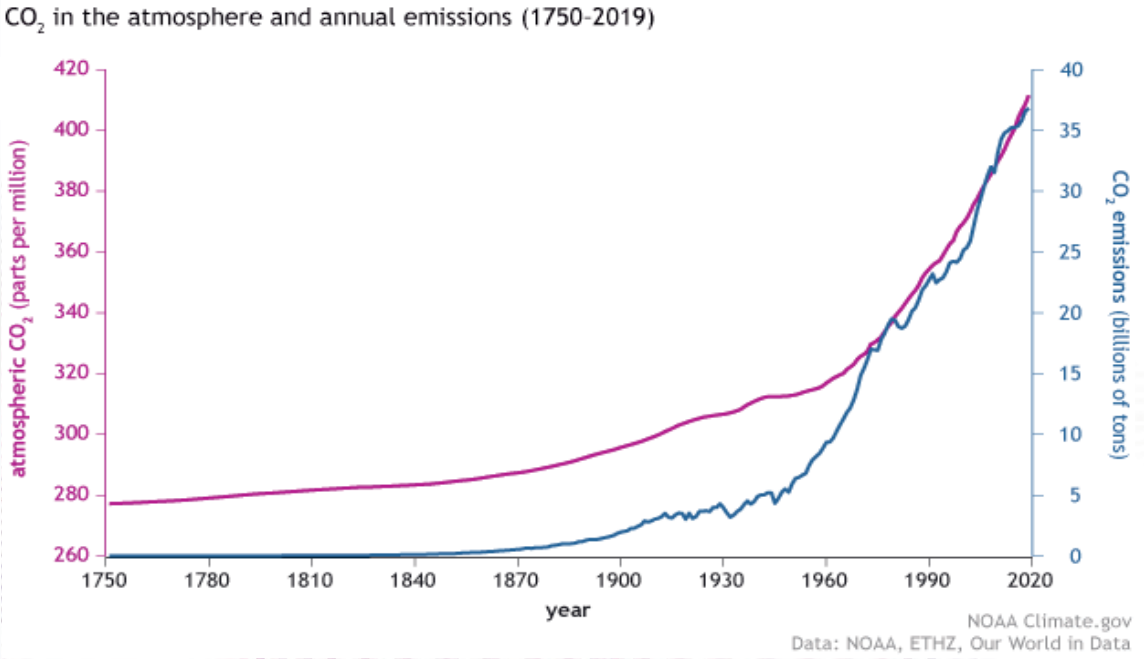


Figure 6.2. Progressive increase of of atmospheric Carbon dioxide concentrations since 1750 GC.

Figure 6.3. Ethiopia's annual CO_2 emission

In nature, CO_2 is exchanged continually between the atmosphere, plants, and animals through photosynthesis, respiration, and decomposition, and between the atmosphere and ocean through gas exchange. A very small amount of CO_2 roughly 1% emitted from fossil fuel combustion, is also from volcanic eruptions. This is balanced by an equivalent amount that is removed by chemical weathering of rocks. The CO_2 level in 2019 was more than 40% higher than it was in the 19th century. Most of this CO_2 increase has taken place since 1970 when the global energy consumption accelerated. The rise in CO_2 is largely from combustion of fossil fuels. Deforestation and other land use changes have also released carbon from the biosphere (living world) where it normally resides for decades to centuries. The additional CO_2 emitted from fossil fuel burning and deforestation has disturbed the balance of the carbon cycle because the natural processes that could restore the balance are too slow compared to the rates at which human activities are adding CO2 to the atmosphere. As a result, a substantial fraction of the CO2 emitted from human activities accumulates in the atmosphere, where some of it will remain for decades or centuries but for thousands of years. Comparison with the CO2 levels measured in air extracted from ice cores indicates that the current concentrations are substantially higher than they have been in at least 800,000 years.

Activity 6.3

Search from different sources (books, internet) about greenhouse gases and their source of emission, and effect. Present your finding to the class.

6.2. Effects of climate change

"You say you love your children above all else, and yet you are stealing their future in front of their very eyes." Greta Thunberg.

Figure 6.4 Greta Thunberg, Climate activist and Founder of Climate School Strike

Self-questioning

Can you explain some of the consequences of climate change?

Climate change destabilizes the earth's temperature equilibrium and has far-reaching effects on human beings and the environment (Figure 6.5). During the course of global warming the energy balance and thus the temperature of the earth change posing a significant impact on humans and the environment. And, it is likely that global warming will increase the probability of extreme weather events.

The direct consequences of man-made climate change include:

rising maximum temperatures

rising sea levels

higher ocean temperatures

an increase in heavy precipitation and shrinking of glaciers

thawing of permafrost

The indirect consequences of climate change which affect humans and our environment include:

- an increase in hunger and water crises, especially in developing countries
- health risks due to the rising air temperatures and heat waves
- economic crisis
- increasing spread of pests and pathogens
- loss of biodiversity due to limited adaptability of flora and fauna
- ocean acidification due to increased HCO_3 concentrations in the water as a consequence of increased CO_2 concentrations

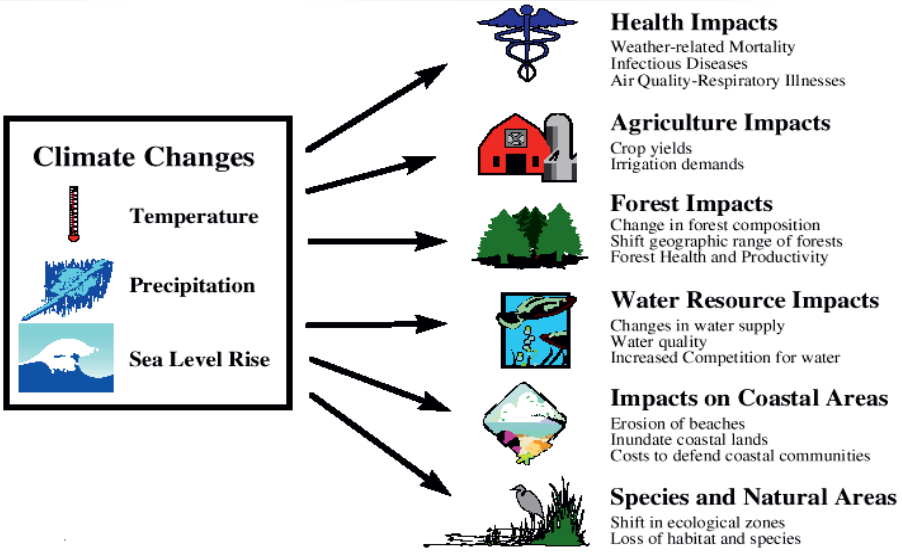


Figure 6.5. Potential climate change impacts

6.2.1. Effects of climate change on biodiversity

Biodiversity provides immense direct benefits to humanswith at least 40% of the world's economy being derived from biological resources. Maintaining biodiversity provides greater food security, opportunities for economic development, and provides a foundation for new pharmaceuticals and other medical advances. However, climate change is affecting the habitats (Figure 6.6) of several species, which they must either adapt or migrate to areas with more favorable conditions. Climate change is likely to become the dominantly direct driver of biodiversity loss by the end of the century. Projected changes in climate combined with land use change and the spread of exotic or alien species are likely to limit the capability of some species to migrate and therefore will accelerate their loss.

Figure 6.6 Changes in rainfall patterns can damage land, plants and animals

6.2.2. Effects of climate change on Agriculture

Agricultural biodiversity refers to all components of biological diversity of relevance to food and agriculture. It includes plants genetic resources, crops, wild plants harvested and managed for food, trees on farms, pastures, rangeland species, medicinal plants and ornamental plants of aesthetic value. Animal genetic resources include domesticated animals, wild animals hunted for food, wild and farmed fish and other aquatic organisms, insect pollinators and microbial and fungal genetic resources. Climate change can disrupt food availability, reduce access to food, and affect food quality. For example, projected increases in temperatures, changes in precipitation patterns, changes in extreme weather events, and reductions in water availability may all result in reduced agricultural productivity (Figure 6.5)

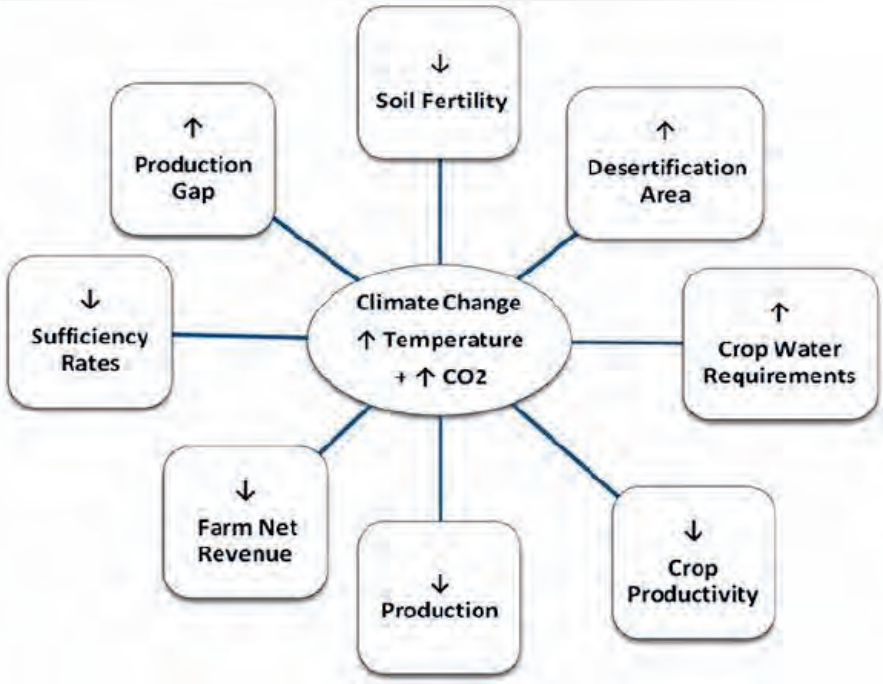


Figure 6.7 Climate change and its potential impacts on Agriculture.

6.2.3. Effect of climate change on forest productivity

Climate change could alter the frequency and intensity of forest disturbances such as pest outbreaks, invasive species, wildfires, and storms. These disturbances can reduce forest productivity and change the distribution of tree species. In some cases, forests can recover from a disturbance. In other cases, existing species may shift their range or die out. In these cases, the new species of vegetation that colonize the area create a new type of forest. Insect outbreaks often defoliate, weaken, and kill trees. Warm temperatures and drought conditions during the early summer triggered wild fire, which can consume millions of acres of forest (Figure 6.8).

Figure 6. 8 Galema forest on fire, Chilalo, Oromia state Ethiopia

6.2.4. Climate change and natural disasters

6.2.4.1. Climate change and natural disasters

Climate hazards are natural events in weather cycles. In our planet we always had hurricanes, droughts and wildfires, high winds and flooding (Figures 6.9 - 6.11). Surprisingly however, we are currently witnessing a scale of destruction and devastation that is new and terrifying. With the increasing global surface temperatures, the possibility of more droughts and increased intensity of storms will likely to occur. As more water vapor is evaporated into the atmosphere, it becomes fuel for more powerful storms to develop.

Activity 6.4

Discuss in a small group about the cause and effects of natural disasters such as flood, land slide and ice melt and the safety rules/ precautions to take during these natural disasters.

Figure 6.9. Heavy rains and storms caused damage and flooding to the Lietchuor camp in Ethiopia, Gambella region.

Figure 6.10 Dust storms in Eastern Ethiopia

6.2.4.2. Melting ice and rising seas

When water warms up it expands. At the same time global warming causes polar ice sheets and glaciers to melt. The combination of these changes is causing sea levels to rise resulting in flooding and erosion of coastal and low lying areas.

6.2.4.3. Extreme weather, shifting rainfall

Heavy rain and other extreme weather events are becoming more frequent. This can lead not only to floods and decreasing water quality but also to decreasing availability of water resources in some regions (Figure 6.11).

Figure 6.11 Failed crops as a result of climate change, Ethiopia

6.2.4.4. Risks of climate change for human health

Climate change is already having an impact on health: There has been an increase in the number of heat-related deaths in some regions of the earth and a decrease in cold-related deaths in other parts of the world. We are already observing changes in the spread of some water-borne illnesses and disease vectors.

Safety rules/ precautions during natural disaster

Disaster risk management is a comprehensive approach involving the identification of threats through implementation of the proposed mitigation measures (Figure 6.10). Natural disasters are catastrophic events that often occur without warning and disrupt the ecosystem causing damage to personal lives, property, transportation, and livelihood. While it is never possible to prevent a disaster, the damage can be minimized through timely preparation. As such, every natural disaster has its own set of precautions to be taken, which must be followed to save precious lives.

Figure 6.12. Elements of Comprehensive risk management

Here under are a few precautions to be taken during natural disasters.

i. Earthquakes

- The shifting of tectonic plates under the earth's crust causes earthquakes, which are responsible for mass destruction. When faced with an earthquake, these tips can be of use:

If you are indoors

- Take cover under a sturdy table or other pieces of furniture, and hold on until the shaking stops.
- Stay away from glass, windows, outside doors and walls, and anything that could fall, such as lighting fixtures or furniture.
- Stay inside until the shaking stops, and it is safe to go outside. Most injuries occur to people trying to move a different location inside the building or try to leave.
- Do not use the elevators.

If you are outdoors,

- Stay away from buildings, streetlights, and utility wires.

- Stand in open ground until the shaking stops. It's dangerous to stay directly outside buildings, at exits, and alongside exterior walls. Ground movement during an earthquake is seldom the direct cause of death or injury. Most earthquake-related casualties result from collapsing walls, flying glass, and falling objects.

ii. Tsunamis

- Tsunamis are a series of enormous ocean waves caused by earthquakes, underwater landslides, or volcanic eruptions. Tsunami waves range from tens to hundreds of feet tall and can travel twenty to thirty miles per hour. When faced with this phenomenon, these tips are to be followed:
    - Turn on your radio/TV to learn and follow the precautionary instructions during a tsunami warning, primarily when you reside near a coastal area.
    - Move inland to higher ground immediately and stay there.
    - Check for a noticeable recession in water away from the shoreline as this is nature's tsunami warning and should be heeded. It would help if you moved away immediately.
    - Stay away from flooded and damaged areas until officials say it is safe to return.
    - Keep yourself away from debris in the water; it may pose a safety hazard to boats and people.

iii. Cyclones

- Cyclones are tropical storms, caused by atmospheric disturbances around a low-pressure area. Cyclones are accompanied by strong winds, moving at a speed of sixty-two Kmph or more. When faced with a hurricane, keep these tips in mind:
- Be alert to the changing weather conditions.
- Listen to radio/TV for the latest information.
- Look for approaching storms.
- Look for the following warning signs: – Dark, often greenish sky – Large hailstones, a large, dark, low-lying cloud (particularly if rotating), roars, similar to a freight train. If you see approaching storms or any of the danger signs, be prepared to take shelter immediately. If you are under a tornado warning, seek shelter immediately. NOTE: In places where you have designated cyclone shelters, take refuge there.

iv. Floods

Floods are among the earth's most common and dangerous natural hazards formed due to a flow of water on areas of land that are usually dry. Excessive rains can damage nearby dams where tsunamis are some of its causes. When faced with flooding, these tips are to be followed:

- Do not attempt to walk, swim, or drive through the floods. Floodwater contains debris and contamination and can also be deadly due to fallen electrical lines in the water.
- Stay clear of bridges over fast-moving water.
- Keep an eye out for evacuation alerts.
- Move to higher ground. If your vehicle is trapped in flood and water starts filling inside the car, seek refuge on the roof.

Mitigation Measure

6.3. International conventions

Climate change is a long-term, global problem. Long-term problems generally require stable but flexible policy implementation over time. Various international conventions have continuously evolved to address the increasingly complex and changing environmental priorities of the world (Figure 6.15).

Activity 6.5

Make a small group and search international conventions from the internet or collect from nearby responsible offices and discuss whether these conventions are implemented as intended in the world and Ethiopia in particular. Report your finding to the class.

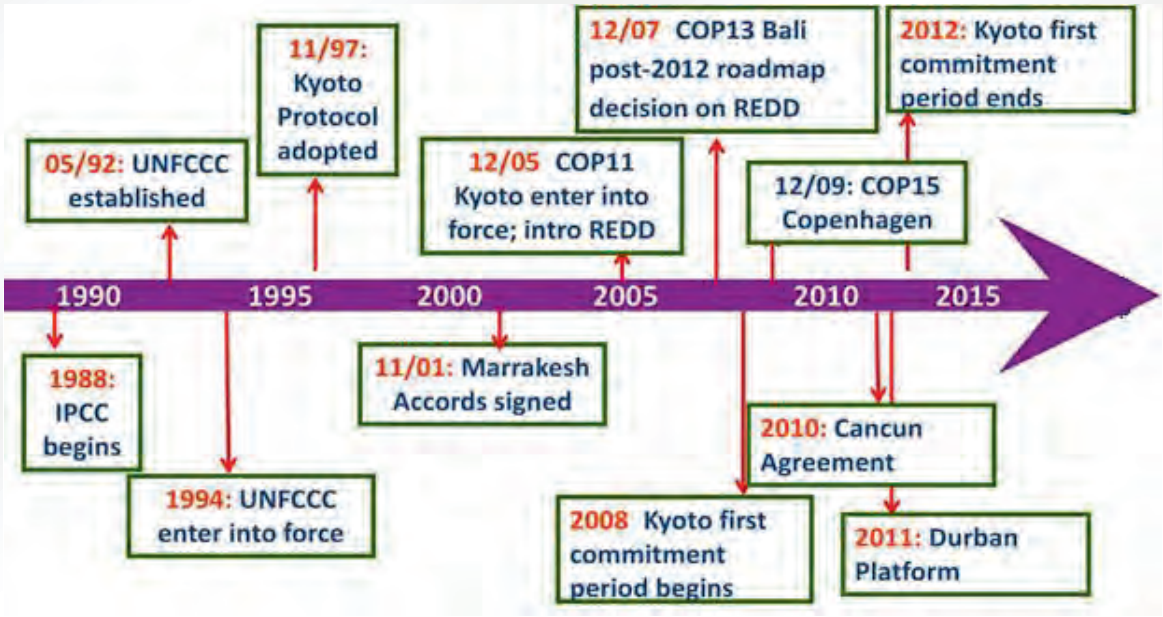


Figure 6.13. Climate Policy Timeline

In 2009 in Copenhagen (COP15), for the first time it was decided that each country would propose a national contribution (INDC, Intended Nationally Determined Contributions). All the 195 UNFCCC countries pledged to reduce their greenhouse gas emissions by 2025-2030.

It aimed "to strengthen the global response to the threat of climate change, in the context of sustainable development and efforts to eradicate poverty" and contained three key provisions:

- Holding the increase in the global average temperature to well below 2 °C above pre-industrial levels and to pursue efforts to limit the temperature increase to 1.5 °C above preindustrial levels, recognizing that this would significantly reduce the risks and impacts of climate change;
- Increasing the ability to adapt to the adverse impacts of climate change and foster climate resilience and low greenhouse gas emissions development, in a manner that does not threaten food production;
- Making finance flows consistent with a pathway towards low greenhouse gas emissions and climate-resilient development.

6.3.1. The United Nations Framework Convention

The United Nations Framework Convention on Climate Change (UNFCCC), agreed in 1992, is the main international treaty to combat "dangerous human interference with the climate system", in part by stabilizing greenhouse gas concentrations in the atmosphere. Its objective is to prevent dangerous man-made interference with the global climate system. The UNFCCC is an international environmental treaty. Ethiopia and all its member countries are among the 197 Parties of the Convention.

6.3.2. Kyoto Protocol on Climate Change

The Kyoto Protocol was adopted on 11 December 1997 The Kyoto Protocol operationalizes the UNFCCC by committing industrialized countries and economies in transition to limit and reduce GHG emissions in accordance with agreed individual targets. That means the Kyoto Protocol is an international agreement that called for industrialized nations to reduce their greenhouse gas emissions significantly. Other accords, like the Doha Amendment and the Paris Climate Agreement, have also tried to curb the global-warming crisis.

First agreed in 1997, it took eight years for participating countries to ratify the Kyoto Protocol (Figure 6.13). The deal was simple. Industrialized countries would be legally obliged to cut their greenhouse gas emissions 5% on 1990 levels by 2008-2012. Developing countries – including China, India, Brazil and South Africa – would face no restriction on their emissions but were encouraged to adopt policies to promote greener growth. To help countries meet targets, Kyoto also offered a range of market mechanisms that could help rich countries offset emissions by investing in low carbon projects in poorer parts of the world. It was hailed as an "environmentally strong and economically sound" deal by US President Bill Clinton, speaking just after agreement had been reached in 1997. "It reflects a commitment from our generation to act in the interests of future generations," he said.

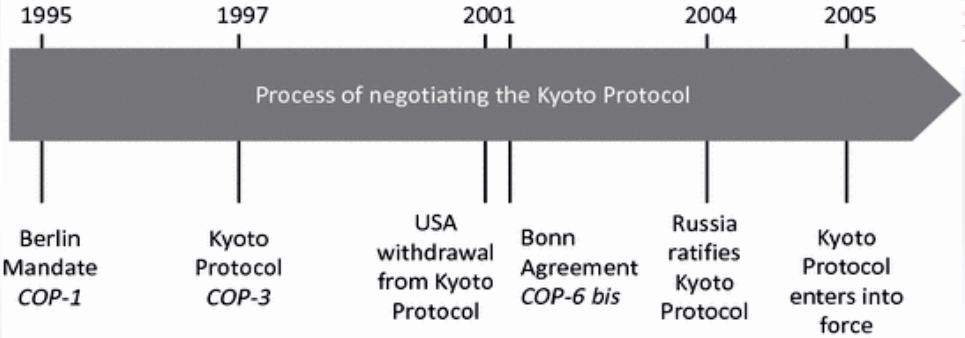


Figure 6.16. The Negotiation process leading to the Kyoto Protocol

6.3.3. International and national practices of Implementation of conventions

Ethiopia Green Legacy Initiave

Ethiopia is one of the world's most drought-prone countries. It has a high degree of vulnerability to hydro-meteorological hazards and natural disasters. Dependence on sectors that are climate change sensitive such as rain-fed agriculture, water, tourism, and forestry as well as a high level of poverty are the main factors that exacerbate Ethiopia's vulnerability.

Ethiopia's policy response to climate change has progressively evolved since the ratification of the UNFCCC in 1994. Ethiopia launched the National Adaptation Plan of Action in 2007 and the Ethiopian Program of Adaptation on Climate Change and Nationally Appropriate Mitigation Actions in 2010. Moreover, Ethiopia endorsed a Climate Resilient Green Economy (CRGE) strategy in 2011 to build a green and resilient economy. Over the years, Ethiopia has been implementing various programs within those policy frameworks. One among them, and by far the most consequential, has been the Green Legacy Initiative (GLI) launched in 2019 with a vision of building a green and climate-resilient Ethiopia and targeted to plant 20 billion seedlings within a period of four years. The Green Legacy Initiative is a demonstration of Ethiopia's long-term commitment to a complicated response to the impacts of climate change and environmental degradation that encompasses agroforestry, forest sector development, greening and renewal of urban areas, and integrated water and soil resources management.

Great Ethiopian Renaissance Dam (GERD)

The Grand Ethiopian Renaissance Dam (GERD) is a hydroelectric dam on the Abay (Blue Nile) River. The GERD is under construction since 2011 with the primary purpose of generating electricity with a capacity of 5.15 gigawatts to relieve Ethiopia's acute energy shortage and for electricity export to neighboring countries. The dam is located in the Benishangul-Gumuz Region and will be the largest hydroelectric power plant in Africa when completed. The GERD is one of éthe best example in Ethioia to support Climate Resilient Green Economy (CRGE) strategy to protect the country against the adverse effect of climate change and to build green economy.

Ethiopia exports electricity to Djibouti and to Sudan and has concluded power export deals and constructed electric transmission line

with Kenya and South Sudan. Ethiopia intends to generate foreign exchange through utilizing all of its potential for producing electricity, mostly from hydropower plants. The enormous amount of electricity generation hydropower like GERD will contribute to the region's economic integrity. Moreover, the lake being created on the GERD will be the biggest lake in Ethiopia with considerable potential for fishing and irrigation development.

Activity 6.6

1. Discuss in a group about the contribution of the Ethiopian Green Legacy Initiative campaign which was launched in 2019 in terms of international protocol implementations. Discuss further what is carbon sequestration, carbon trading and their link to the Green Legacy Initiative.

2. Discuss in a group about the contribution of GERD to support green economy and avert the adverse effect of climate change.

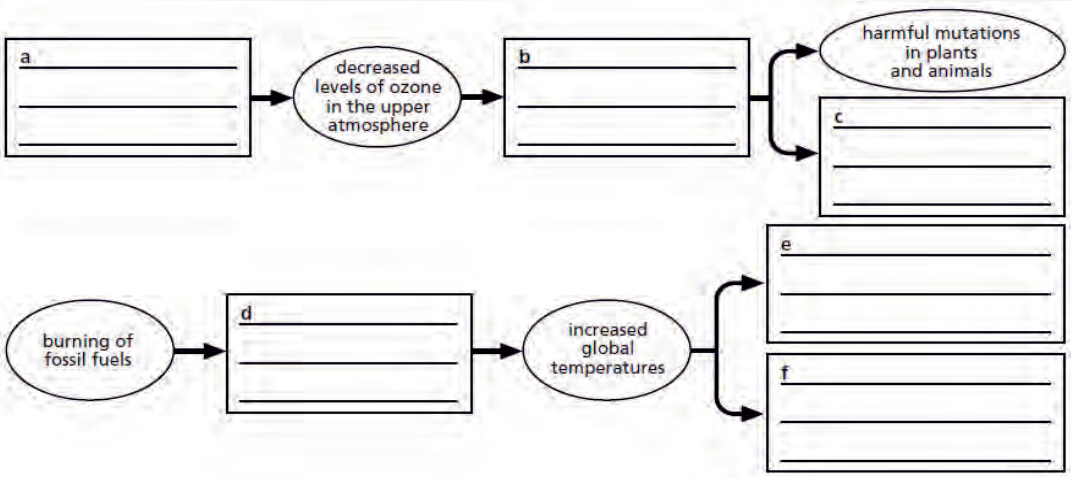
Unit Summary

In this unit you have learnt that climate change is the global phenomenon of climate transformation characterized by the changes in the usual climate of the planet which are largely caused by human activities. Natural and anthropogenic substances are the main causes of climate change. Human activities increasingly influencing the climate and the earth's temperature by burning fossil fuels, cutting down forests and farming livestock that increases the concentration of atmospheric Carbon dioxide (CO_2). Greenhouse gases (GHGs) such as water vapour, Carbon dioxide, methane and nitrous oxide are the major GHGs in the earth's atmosphere that trap heat. When Greenhouse gases are released into the atmosphere at various scopes they influence the earth's energy balance by trapping heat in the atmosphere, which makes the Earth warmer. Since the Industrial Revolution, human activities have added very large quantities of GHFs into Earth's atmosphere and has brought significant effect to the world. The effect of climate change has both direct and indirect consequences to humans. To tackle the effects of climate change several mitigation measures have been set globally. However, much work is expected from all countries to effectively implement international conventions and policies.

Unit review questions

Answer the following questions

1. What is climate change? Explain how it differs from global warming?
2. How does climate change affect human health?
3. How is agricultural productivity related to climate change?
4. Describe some of the climate change conventions
5. What is climate change mitigation?
6. The flowcharts below represent some of the effects of human activity on the environment. Each arrow indicates a known or suspected cause and-effect relationship. Complete the flowcharts by writing an appropriate response in the space corresponding to each box.


a
decreased levels of ozone in the upper atmosphere
b
harmful mutations in plants and animals
c
burning of fossil fuels
d
increased global temperatures
e
f