BIOLOGY

Distance Education Module
Grade 12

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BIOLOGY DISTANCE EDUCATION GRADE 12

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Distance Education Module
TWO
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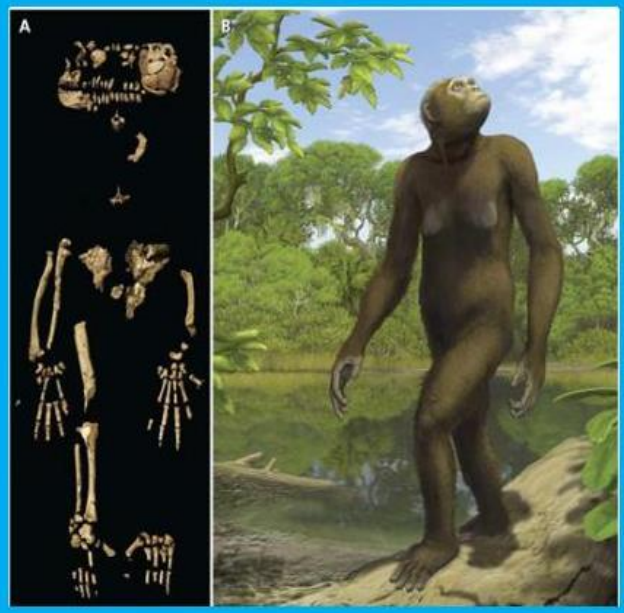

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MINISTRY OF EDUCATION

Biology

DISTANCE EDUCATION MODULE

GRADE 12

Module TWO

Evolution, The human Body System and Climate Change

Federal Democratic Republic of Ethiopia Ministry of Education

Module Two

Evolution, The Human Body System and Climate Change

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This is the second module of grade 12 Biology designed as a distance material for learners. The module consists of three units, namely Evolution, The human body system and Climate change to be covered in one semester. Each unit is organized into sections that include Introduction, sub topics, activities followed self-evaluation checklist and self –test exercises. At the end of each unit there is unit summary, feed – back to activities and answer key for self – test exercises.

Even though there are different specific learning strategies / learning methods for the different sections, the following general learning strategies are suggested to study this module:

- Rehearsal /Retrieval practices – Constructing mind or mental map, preparing short notes, checking course materials to fill gaps in memory
- Elaboration practices - paraphrasing, creating analogies, question and answering
- Self- Evaluation practices – Using checklist, rereading /reviewing, generating self- test questions
- Self- regulating practices : allocate specific study time (prepare daily time table or weekly pattern or some other types of arrangement), designate defined, quiet and organized area to study, adjust learning rate, respect schedule and finish activities and exercises in time

In this module, you will find the following icons or graphic symbols with the description they represent throughout the module.

This tells you there is an overview, specific note for the topic and/or sub topic

.

This tells you there is question to answer or think about in the text

This tells you to take not of or to remember an important point.

.

This tells you there is an activity for you to do

This tells you there is a checklist.

This tells you there is a sel-tes exercise

This tells you there is a written assignment

This tells you that there is a keyword. Moreover, it is used to tell you a key to the the self-test exercises.

Dear distance learner, if you encounter difficulty in understanding some topics in the module, do not get frustrated or discouraged. Take it as a challenge. Do not give up! Keep in mind that you are self – learner practicing individual learning. Do not forget that other distance learners too may experience similar difficulties as you encountered.

When some topics are difficult to understand, first go through the module over and over again until you get things clearer. If you are not able to succeed, do not hesitate to get the support of teachers in the nearby school or knowledgeable experts from other sectors or exchanging information with another distance learner and regular students through virtual meetings using your smart phones. Additionally, you should be aware that tutors will be assigned to you in each tutorial center. As a result, you can get in touch with your tutors if you run into any problems. You can ask your instructors about the module's sections that you don't understand and even the activities that, in your opinion, are unclear or difficult to answer. You can also bring your module, your responses to the module's activities, and any challenging topics you think your tutor should hear about and help you.

As a final advice, you should do all the activities and self- test exercises by yourself before proceeding to the feedback or answer key for self- test exercises.

Assessment techniques

One or more of the following assessment methods can be used while you are studying the module to see if you have done so successfully:

- After each section in the module, there is a self-evaluation check list to which you should respond.
- Self-testing exercises are provided after each lesson that you are required to complete. Do not rush to look at the answers provided at the end of the unit when you are completing the self-test exercises. Answer the questions first, then review your answer on the answer sheet.
- You will have "Assignment questions" at the end of the each unit. You are required to complete the assignment's questions and submit it to your tutorial center so that it can be corrected.
- Try to respond to each and every in-text and lead questions throughout your study sessions. Before moving on to the next section, these questions will assist you in reading additional materials (including books, the internet, and other sources).
- Final examination: Following successful completion of the module, you will take a final examination at your tutorial center.

Contents

Module Two

Introduction to the Module

Dear learner,

We trust that you have successfully completed the first module, which comprises of three units. Moving forward, you will now embark on the second module, which is a continuation of the first. This module also has three units: **Evolution**, **Human Body System**, and **Climate Change**. The Evolution unit covers theories on the origin of life and evolution, human evolution, and evidence of evolution, all of which are extensively discussed. In the Human Body System unit, you will learn about the human nervous system, its parts, nerve impulse and transmission, and different types of sense organs. Lastly, the Climate Change unit delves into the causes of climate change and different types of mitigation mechanisms used to avoid it. We highly encourage you to dedicate your best efforts towards learning and successfully finishing this module.

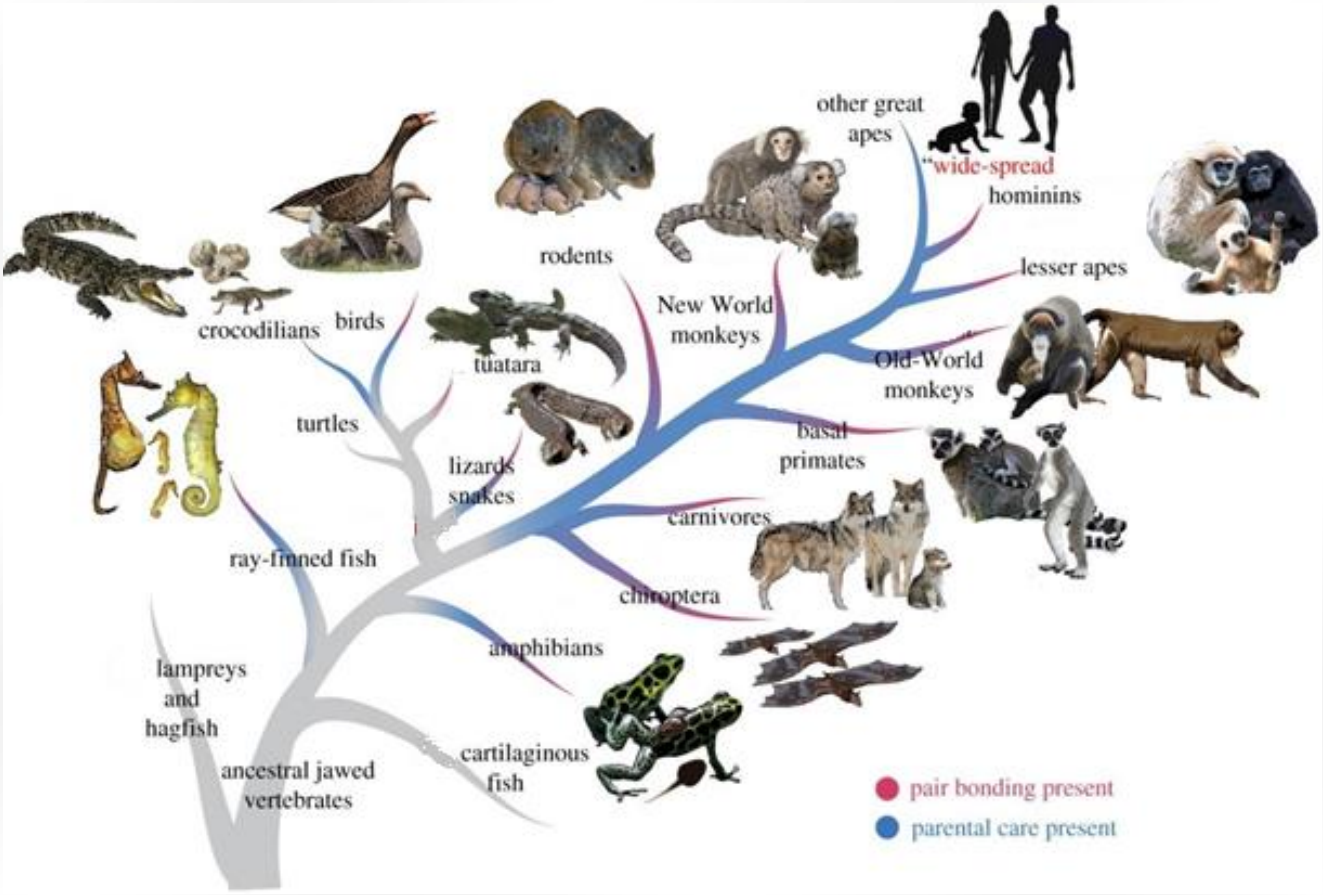
Module Objectives

Dear learner, this module contains three units. After completing the units in the module you will be able to:

- Explain different views about the origin of life
- Describe scientific evidence that supports modern living things have evolved from a common ancestor.
- Explain the major causes of evolution that lead to variation in organisms
- Describe the role of natural selection and survival of the fittest in evolution and day to day life
- Explain the structure and its functions of nervous system
- Discuss how the nervous and endocrine system works
- 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

- Describe the effects of drug abuse on the normal functioning of the nervous and endocrine system
- Describe the key scientific concepts of climate change.
- Explain 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
- Describe implementation practice of international conventions to mitigate climate change

UNIT ONE: EVOLUTION



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Unit One

Unit overview

Dear learner, welcome to the first unit of the second module. This unit will cover different perspectives on the origin of life, theories of evolution, and the different types of evidence that support it. You will also learn about the major causes of evolution that result in variations in organisms, and the important role of natural selection and survival of the fittest in evolution and daily life. It sounds like an exciting unit and I wish you all the best in your studies!

Unit learning outcomes

Dear learner, after successful completion of this unit, you 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.

Unit study time (23 hrs)

Dear leraner, the required time to accomplis unit one is 23 hrs. You should use the allocated time properly to cover the contents of the first unit.

Section 1.1 Definition

Dear learner, at the end of this section you will be able to:

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

What is evolution?

What do you understand about evolution? how do you explain 'evolution'?

Have you ever wondered how all millions of new species appeared on our planet?

Dear learner, **evolution** is the process of change and development in living organisms over time. Evolution occurs through a combination of different mechanisms, including natural selection, genetic mutation, genetic drift, gene flow, and reproductive isolation. Meiosis, hybridization, and mutation all play important roles in the process of evolution.

Keyword

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

Natural selection is a process that leads to the adaptation and alteration of populations of living organisms. Individuals within a population exhibit natural variations, making them different from each other in many ways. This variation is significant as some individuals possess traits that are more suited to the environment than others. Those individuals that have adaptive traits, which give them a competitive advantage, are more likely to survive and reproduce. Meiosis is a type of cell division that occurs during the formation of gametes (sex cells). It is responsible for creating genetic diversity by randomly shuffling and recombining alleles from both parents. This recombination during meiosis leads to the production of genetically unique offspring, increasing genetic diversity within a population. The new combinations of genetic information generated through meiosis can give rise to new traits or variations that may be favored by natural selection.

Hybridization occurs when individuals from two different species or populations interbreed, resulting in offspring with a mix of traits from both parental groups. This can introduce new combinations of genes and genetic variation into the population, potentially leading to the emergence of new species or subspecies. Hybridization plays a significant role in speciation events, where two divergent

lineages come into contact and interbreed, contributing to the formation of new evolutionary branches.

Derar learner, the other important mechanism for evolution is mutation. **Mutations** are random changes in the DNA sequence that can result in new versions of genes (alleles) being created. These new alleles can lead to the development of new traits or variations in existing traits. Mutations can occur spontaneously or can be induced by various factors such as exposure to radiation or certain chemicals. While most mutations are neutral or harmful, occasionally a beneficial mutation can arise, giving the organism carrying it a selective advantage. Over time, the accumulation of these beneficial mutations can drive evolutionary change and adaptation.

Dear learner, you may find it interesting to understand that meiosis, hybridization, and mutation are all important mechanisms that contribute to the genetic diversity within populations. This diversity is what allows for the potential for adaptation and the formation of new species through the gradual process of evolution. Meiosis is a process of cell division that produces genetically diverse gametes, while hybridization is the crossing of two genetically different individuals to produce offspring with unique combinations of traits. Finally, mutation is the random changes in DNA sequence that can create new versions of genes, leading to the development of new traits. Together, these mechanisms play a crucial role in shaping the genetic makeup of populations over time, allowing them to adapt to changing environments and giving rise to new species.

Section 1.2 Theories of the origin of life

What are the known theories of origin of life?

Dear learner, the emergence of heritable and evolvable self-reproduction, known as the origin of life, is a complex and sometimes controversial topic. For a considerable period, there were two opposing theories, namely **intelligent design** and **creationism**. However, the **Big Bang** theory of the Universe's origin has sparked new ideas about biological evolution. Scientists have hypothesized that the evolution of complex life forms on Earth, including humans, resulted from a process of self-organization similar to simple material structures' evolution into more complex ones. Various theories exist about the origin of life, and the creation of life on Earth may raise more questions than answers. This section provides an overview of some of the origin of life theories.

1.2.1 Special creationism

Dear learner, the concept of **special creationism** proposes that life on Earth was created through the intervention of **supernatural** or **divine forces**. This idea is fundamentally distinct from the scientific perspective. Special creationism suggests that life on Earth was created by a supreme being at some point in time. However, the specifics of this theory vary significantly across different religions, and there are diverse interpretations of the doctrine within each religion.

Keyword

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

Activity 1.1

Dear learner,

Are you interested in learning more about creationism theories? Let you dive in and compare how they are similar and different. By studying the following theories, you can discover what makes each one unique:

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

1.2.2 Spontaneous generation

What does the theory of spontaneous generation states?

☸ Dear reader, it is fascinating to look back into history and learn about the different theories that people used to believe in. **The theory of spontaneous generation**, which suggested that life could arise from non-living things, was one such belief that was held by many people in the past. Even the ancient Greek philosopher Aristotle (384–322 BC) believed in this theory. It was thought that various living organisms like mice, flies, maggots, and fish could arise from non-living things like corn, cow manure, decaying meat, and dried lake mud. Flemish scientist Jan Baptista van Helmont (1580 – 1644) even proposed that mice could appear from rags and wheat

Keyword

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

kernels left in an open container for three weeks.

Can you describe how and why mice flourish or appeared in Jan Baptista van Helmont experient?

Dear learner, the theory of spontaneous generation persisted into the 17th century. However, in 1668, **Francesco Redi**, an Italian scientist, conducted a scientific experiment to test the spontaneous creation of maggots. He placed fresh meat in jars, leaving one jar open and covering the others with a cloth (See Figure 1.1). After a few days, he observed that the open jar contained maggots, while the covered jars contained none. Upon further examination, he noticed that the maggots were found on the exterior surface of the cloth that covered the jar. Redi successfully demonstrated that maggots come from fly eggs, which helped disprove the theory of spontaneous generation

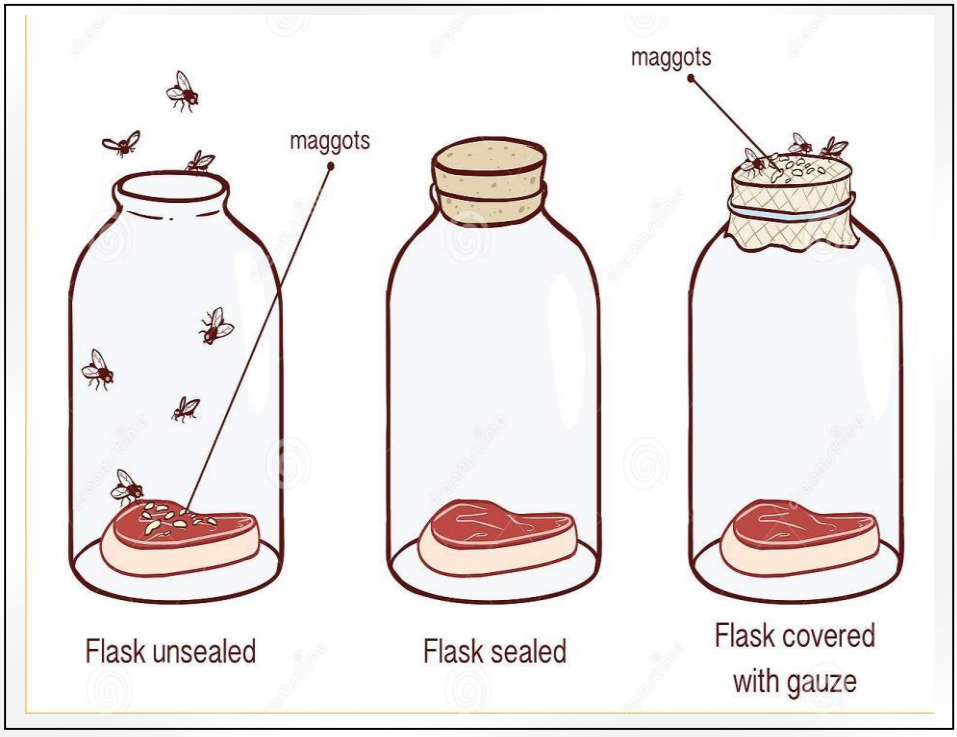

Figure 1.1 Fransesco Redi's experiment set up.

Louis Pasteur, the renowned French scientist, demonstrated that the souring of broth or wine is the result of the entry of micro-organisms. Through his experiments, he established that micro-organisms do not spontaneously appear in the broth, but rather originate from external sources (See Figure 1.2).

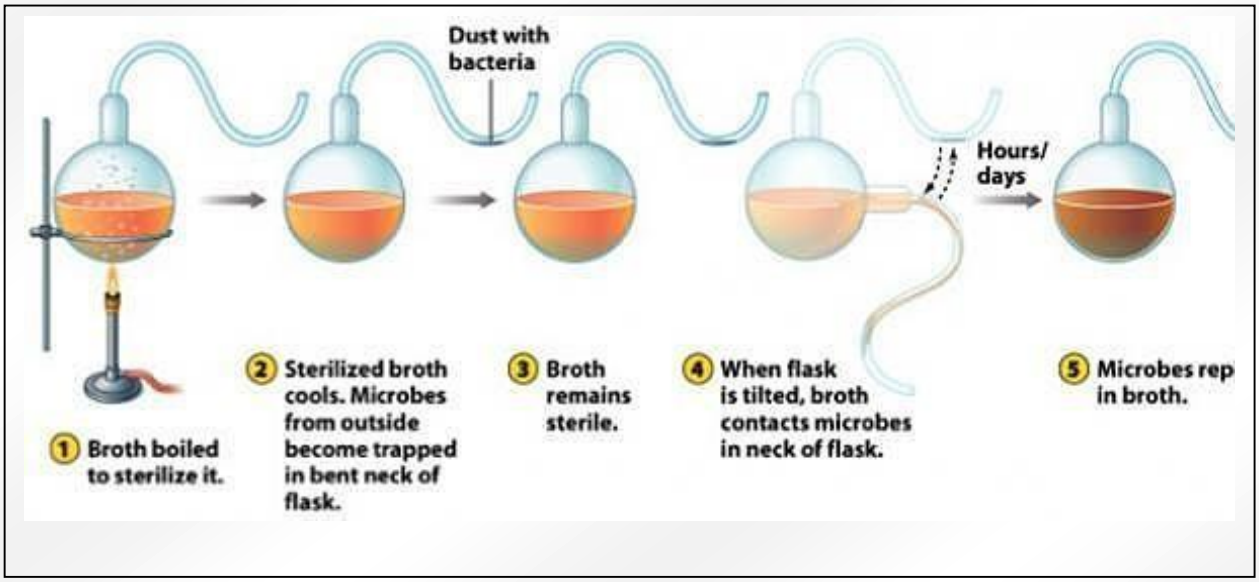

Figure 1.2 Louis Pasteur's experimental set up to disprove spontaneous generation

Dear learner , these two scientists, Redi and Pasteur, showed that both macro-organisms (Redi) and micro-organisms (Pasteur) could only arise from pre-existing organisms, disproving the theory of spontaneous generation.

. Dear learner, can you explain how Francesco Redi and Louis Pasteur disproved the theory of spontaneous generation?

1.2.3 Theory of Eternity of life

What is the theory of Eternity of life?

Dear learner, according to the theory of the eternity of life, life on Earth has neither a beginning nor an end. Therefore, it doesn't require 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 has always existed, just like the Universe itself. At the time when these theories were being proposed, many renowned scientists, including Albert Einstein, believed that the Universe was unchanging. They reasoned that if life exists in an unchanging Universe today, it must have always been present.

Keyword

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

1.2.4 Cosmozoan theory, Panspermia or Spore broth theory

How do you explain Cosmozoan theory of life?

Activity 1.2

Dear learner, how does the panspermia theory propose that life could have been transferred from other planets or celestial bodies to Earth?

Figure 1.3 A meteorite fall

Dear learner, there's a theory called **the cosmozoan theory** that suggests life may have come to Earth from other planets as highly resistant microorganism spores. This idea was first proposed by Richter in 1865 and later supported by Arrhenius in 1908. These spores are referred to as **cosmozoa** or **panspermia** because they can survive space travel and are preserved inside meteorites. According to the cosmozoan theory, life on Earth may have originated when these spores or other particles containing "protoplasm" arrived from an unknown part of the universe, along with cosmic dust. Helmholz (1884) even speculated that falling meteorites may have brought "protoplasm" to Earth. However, there's currently limited evidence to support this theory.

Keyword

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

1.2.5 Biochemical origin of life

How do you describe the basis of the biochemical theory for the origin of life?

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.*

Dear learner, two biologists from the early twentieth century played a significant role in our current understanding of abiogenesis, which refers to the biochemical reactions that could have led to the evolution of life on Earth.

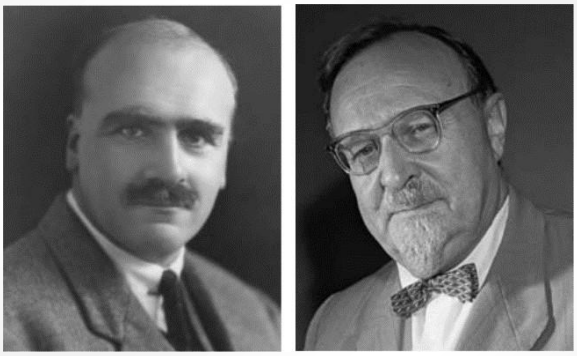

Figure 1.4 J B S Haldane and A I Oparin

Figure 1.5 Clouds of inter-stellar gas have been shown to contain organic molecules

In 1924**, Aleksandr Oparin**, a Russian biologist, proposed that common gases in the early Earth atmosphere combined to form simple organic chemicals, which in turn combined to form more complex molecules. Independently, in 1929, **John Haldane**, an English biologist, put forward almost identical ideas before Oparin's book had been translated into English. The complex molecules separated from the surrounding medium, acquired some of the characteristics of living organisms, and were able to absorb nutrients, grow, divide (reproduce), and so on. Later, **Miller** approved the Oparin-Haldane model by mixing the basic elements

to produce simple organic compounds and combining them

to produce the building blocks of proteins and nucleic acids (See Figure 1.7).

Figure 1.6 Coacervate droplets – pre-cells

Activity 1.3

Dear learner**,** how did Stanley Miller's experiment contribute to our understanding of the biochemical origins of life?

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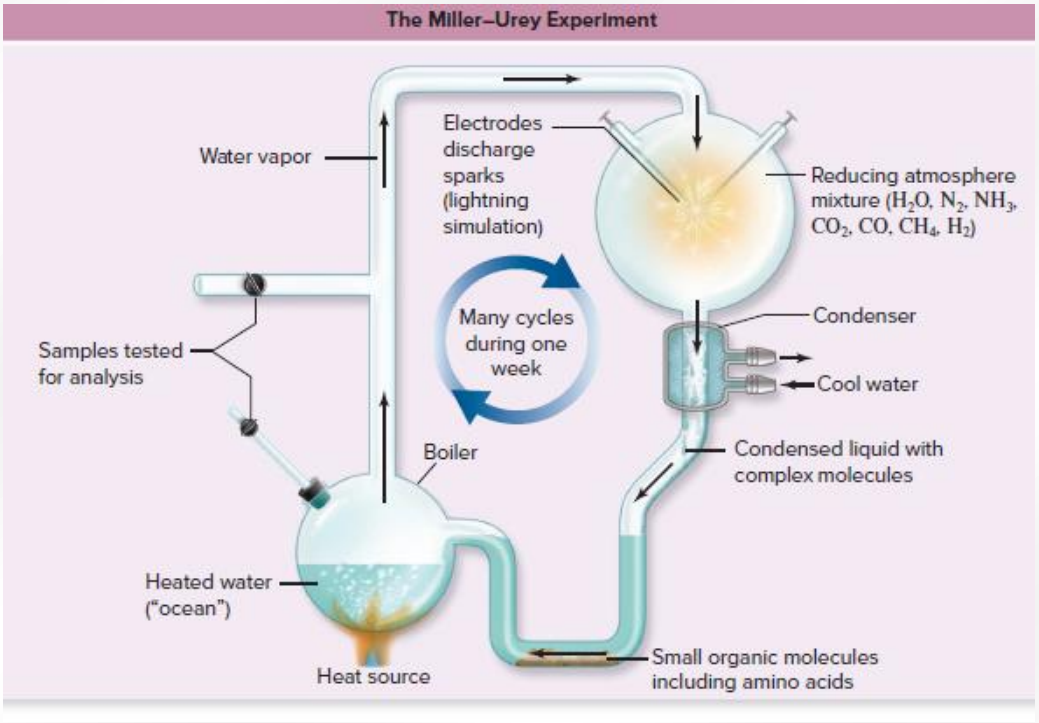


Figure 1.7 Stanley Miller's spark-discharge.

Autotrophs

How do primitive autotrophs (photoautotrophs and chemoautotrophs) contribute to life on earth?

Activity 1.4

Dear learner, what are the main characteristics of photoautotrophs, and how do they obtain energy differently from chemoautotrophs?

Dear learner, the first organisms that appeared about 4 billion years ago were prokaryotes. They had no true nucleus. It seems likely that they had RNA rather than DNA as their genetic material. They likely gave rise to three distinct lines of evolution leading to:

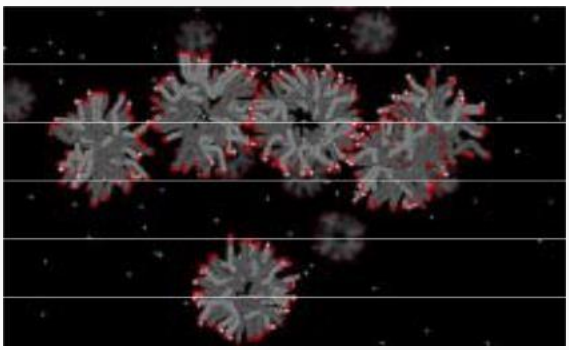


Figure 1.8 Pre-cells resembled this configuration during division.

- **Archaebacteria** – prokaryotes including thermophilic sulphobacteria, methanobacteria andhalophilic bacteria
- **Eubacteria** – prokaryotes; ordinary bacteria and cyanobacteria (blue-green bacteria andsometimes known as blue-green algae).
- **Eukaryotes** – eventually evolving into protoctistans, fungi, plants, animals (nearly all areaerobic).

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. Where did this oxygen come from?

Keywords

Autotroph *is an organism that produces organic molecules from inorganic material*
Aerobic respiration is *a means by which cells release energy from organic molecules using oxygen*
Prokaryote *is an organism that consists of a prokaryotic cell. All bacteria are prokaryotes*
Eukaryote *is an organism that consists 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*
Photosynthesis *is the use of light energy to drive reactions that synthesize organic molecules; it occurs in plants, algae and some bacteria.*

Chemoautotophs

Chemoautotrophs use the energy from chemical reactions to synthesize all necessary organic compounds, starting from carbon dioxide. Generally, they only use inorganic energy sources. Most are bacteria or archaea that live in hostile environments such as deep sea vents and are the primary producers in ecosystems on the sea beds. Scientists believe that some of the first organisms to inhabit Earth were chemoautotrophs. The primitive

sulphobacteria use hydrogen sulphide as the energy source. Hydrothermalism, particularly in deep sea vents, maintains the bacterial life of sulphobacteria and/or methanobacteria. Bacteria are the only life forms found in rocks for a long time, 3.5 to 2.1 billion years ago. Eukaryotes became numerous 1.9 to 2.1 billion years ago and fungi-like organisms appeared about 0.9 billion years ago.

The oxygen produced by the photoautotrophs had made it possible for aerobic respiration to evolve as an energy-releasing pathway. As this process releases far more energy than does the anaerobic pathway more active organisms could now evolve animals, perhaps 600 to 700 million years ago.

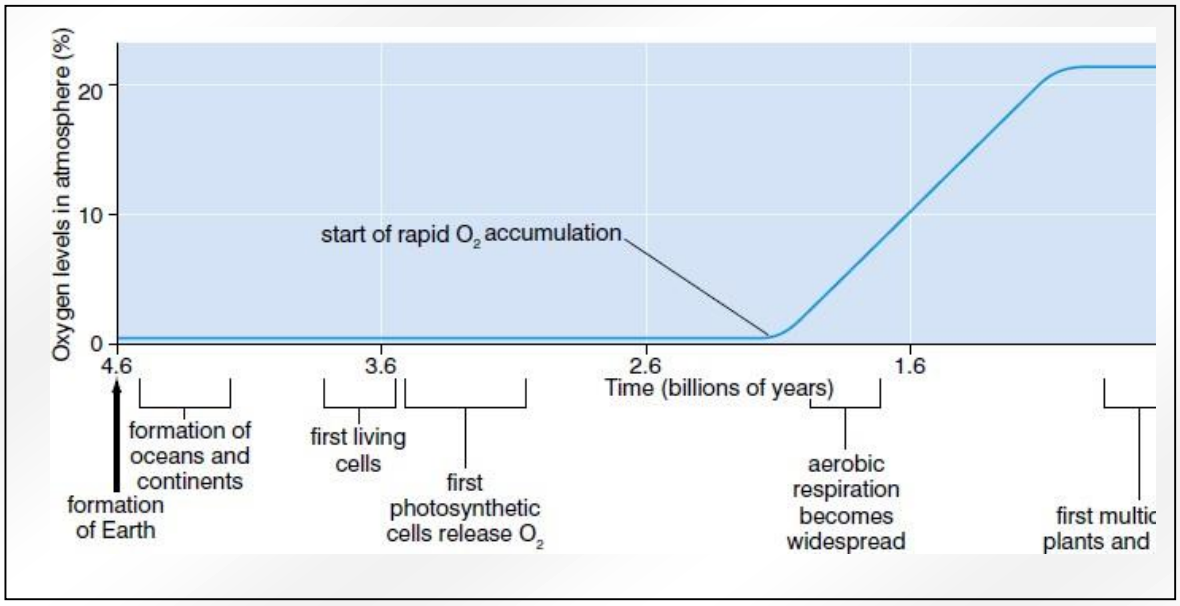


Figure 1.9 Life on Earth has evolved over billions of years

Photoautotrophs

Could you clarify the dissimilarity between photoautotrophs and photoheterotrophs?

Dear learner, photoautotrophs are organisms that can make their own energy using light and carbon dioxide through the process of photosynthesis. The word photoautotroph is a combination of autotroph, the word for an organism that makes its own food, and the prefix photo-, which means “light”. Green plants, algae, and some bacteria are examples of photoautotrophs. Photoheterotrophs are organisms which also make

energy from light but cannot use carbon dioxide as their sole source of carbon, and instead use organic materials.

☑ Self-evaluation checklist

Put a tick (✓) against each of the following tasks which you can perform.

Can you analyze the different views of theory of origin of life listed below and evaluate them from a scientific explanations point of view?

Special creationism theory	☐
Spontaneous generation	☐
The theory of Eternity of life	☐
Cosmozoan theory of life	☐
Panspermia or spore broth theory	☐
Biochemical origin of life	☐
Chemoauotrophs and photoautotrophs	☐

🛠 Self-test exercise

Choose the correct answer

1. The theory that states that all forms of life were created about 6000 years a go in the forms they hold now is:
   A. cosmozoan theory of origin of life
   B. theoy of spontaneous generation
   C. theory of special creationism
   D. theory of biochemical origin
2. One of the following initiates evolution
   A. variation
   B. mutation
   C. extinction
   D. adaptation
3. Spontaneous generation has suggested that:
   A. life can be created from non-living matter
   B. all life forms are eternal
   C. organic molecules arrived on Earth in meteorites
   D. all of the above

4. The eternity of life theory suggests that:
   A. life can be created from non-living matter
   B. life has always existed and always will
   C. organic molecules arrived on Earth in meteorites
   D. all of the above

5. Francesco Redi and Louis Pasteur disproved

   A. the theory of spontaneous generation?

   B. cosmozoan (panspermia) theory of life

   C. biochemical theory of life

   D. eternity of life theory

6. All forms of the cosmozoan (panspermia) theory suggest that:
   A. life can be created from non-living matter
   B. life forms arrived on Earth due to radiation pressure
   C. organic molecules arrived on Earth in meteorites
   D. none

7. All forms of the biochemical theory (abiogenesis) suggest that:
   A. organic molecules arrived on Earth in meteorites

   B. life on Earth originated as a result of a number of biochemical reactions producing organic molecules which associated to form cells.
   C. life forms arrived on Earth due to radiation pressure
   D. none

8. The first photoautotrophic organisms were likely to have been:
   A. green algae
   B. sulphur bacteria
   C. plants
   D. blue-green bacteria

9. Which of the following is the best definition of a chemoautotroph?
   A. an organism that uses chemical reactions as a source of energy.
   B. an organism that uses chemical reactions as a source of energy to absorb its food.
   C. an organism that uses chemical reactions as a source of energy to synthesise its own food.

D. an organism that uses chemical reactions as a source of energy to synthesise organic molecules, using carbon dioxide as a starting point.

10. The scientists who developed the theory of biochemical or abiogenesis were:
    A. Miller and Bernal
    B. Miller and Oparin
    C. Bernal and Haldane
    D. Oparin and Haldane

Section 1.3 Theories of evolution

Dear learner, in this section, you will be able to:

- Compare Lamarck Vs. Darwinian theory

Dear learner, in the previous section, you explored the diverse theories regarding the origin of life. We trust that you have acquired a better understanding of the various perspectives on this topic. Next, you will learn the fascinating realm of evolution and its theories.

1.3.1 Lamarckism

How do you explain Lamarck theory of evolution?

Jean-Baptiste De Lamarck (1744 - 1829) was a prominent French naturalist known for his naturalistic explanation of the diversity of modern organisms and animals found in the fossil record. He introduced the theory of Lamarkism, which suggests that physical changes in organisms throughout their lifetime, such as the enhanced development of an organ or a body part due to increased use, can be inherited by their offspring. In 1809, he presented the concept of "the inheritance of acquired characters." Here are the fundamental principles of Lamarck's theory:

A) New Needs: Changes in environment factors such as 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 including changes in habits or behavior.

B) Use and disuse of organs: The new habits involve the greater use of certain organs to meet newneeds, 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 offspring so that these are born fit to face the changed environmental conditions and the chances of their survival increased.

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

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.*

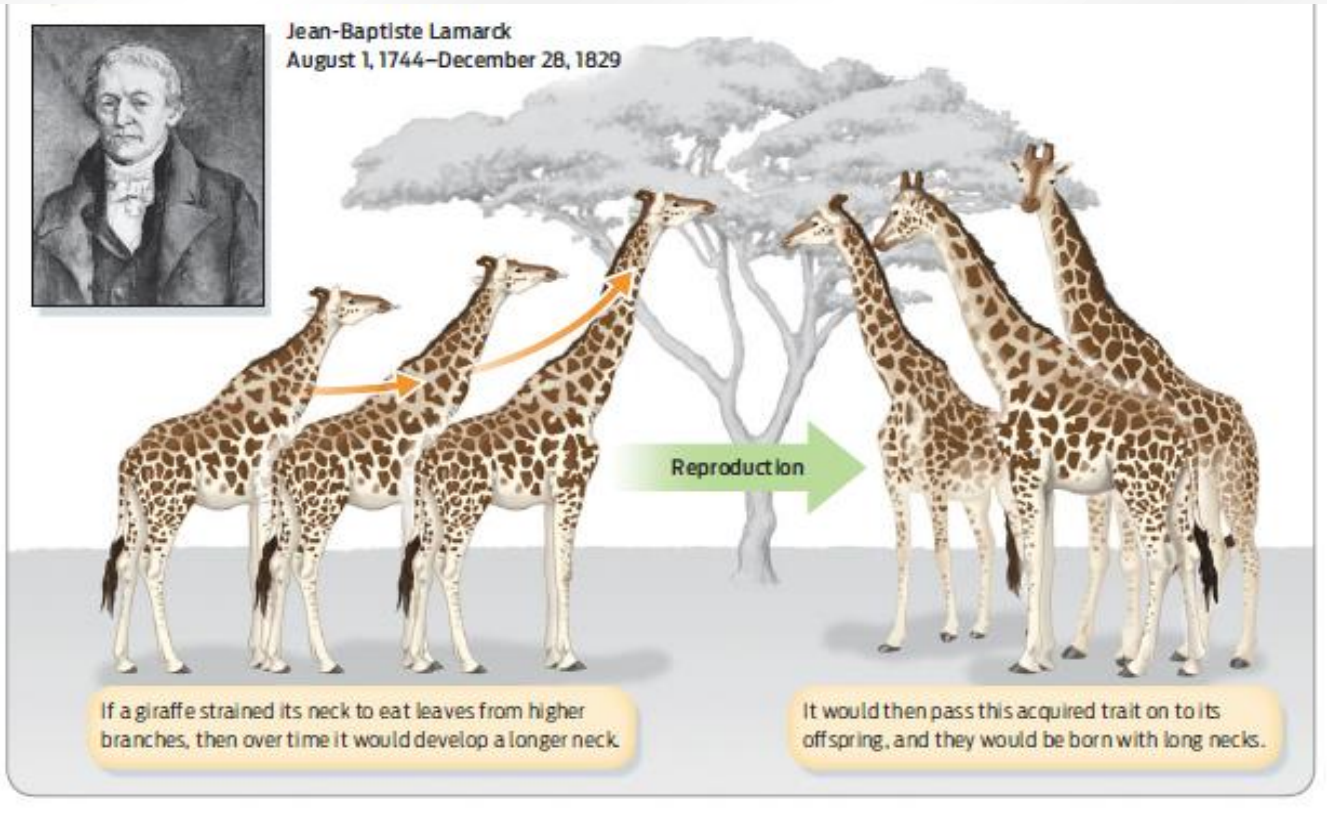


Figure 1.10 Lamarck's ideas of use and disuse and theinheritance of acquired traits of evolution

Use and disuse

What types of examples were used by Lamarck to explain the concept of use and disuse?

Dear learner, in this section of his theory, Lamarck suggests that structures or processes that are frequently utilized have a tendency to increase in size or become more developed. On the other hand, structures or processes that are rarely used will decrease in size or become less developed. Lamarck illustrates this concept by using the elongated neck of a giraffe as a classic example. According to Lamarck, a giraffe could gradually stretch its neck to reach high branches and consequently develop an elongated neck. However, Lamarck was unable to provide an explanation for how this process occurs.

Could you please explain what vestigial organs are?

Dear learner, it is important to understand the concept of **vestigial organs** according to Lamarck's theory of use and disuse. According to this theory, if an organ is continuously and

frequently used by a generation, it becomes more developed over time. On the other hand, if an organ is frequently unused by a generation, it will eventually become extinct. A prime example of a vestigial organ in humans is the appendix, which becomes extinct due to continuous disuse.

Inheritance of acquired traits

How Lamarck explained the 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 acquired long necks would have offspring with long necks even if they were born with the short necks inherited from their parents. 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 and constantly.

Significance of Lamarckism

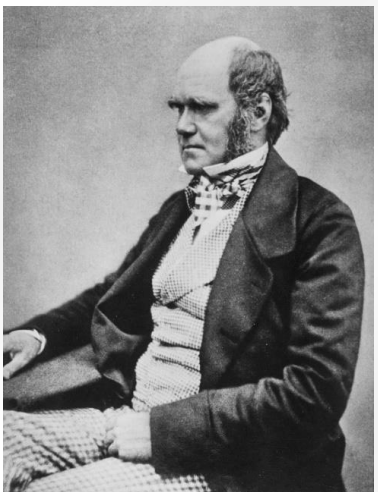
Dear learner, Lamarckism provided orders on how organisms could acquire modifications. The folloing are significance of Lamarck theory of evolution.

a) It was the first comprehensive theory of biological evolution.
b) It nicely explains the existence of vestigial organs in animals due to their continuous disuse.
c) It explains the development of strong jaw muscles and claws in carnivores due to theircontinued extra use.
d) It stimulated other biologists to look for the mechanism of organic mechanism.

1.3.2 Darwinism (Theory of natural selection)

How do you explain Darwin's theory on the origin of species?

Dear learner, **Charles Darwin** and **Alfred Russel Wallac**e jointly proposed the **theory of natural selection** to explain how evolution occurs. According to this theory, organisms produce more offspring than can survive in their environment, and only those with the best physical fitness are able to survive, grow, mature, and reproduce.



Individuals that lack such fitness do not reach maturity or produce fewer offspring than their fitter counterparts. Natural selection can be summed up as **"survival of the fittest,"** as those organisms best suited to their environment are the most successful at reproducing and passing on their traits to the next generation.

Dear learner, Charles Darwin was influenced by other early thinkers such as Lamarck, Lyell, and Malthus. He was particularly inspired by an essay titled ‘Principle of geology’ written by Charles Lyell. One of the key sources of evidence for Darwin's theory of evolution was his visit to the Galapagos Islands. These islands are a small group located in the Pacific Ocean, around 600 miles off the coast of Ecuador in South America. During his visit, Darwin visited five of the Galapagos Islands and made drawings and collected specimens. Darwin's observation of the finches found on the different islands was particularly important. He noted that although there were many similarities between them, there were also obvious differences. After studying the finches, he concluded that an ‘ancestral finch’ had colonized the islands from the mainland. In the absence of predators, the finch was able to adapt to different conditions on the islands and eventually evolved into different species (See Figure 1.12). For example, some of the finches with pointed beaks evolved into insect eaters, while others with beaks capable of crushing seeds evolved into seed eaters.

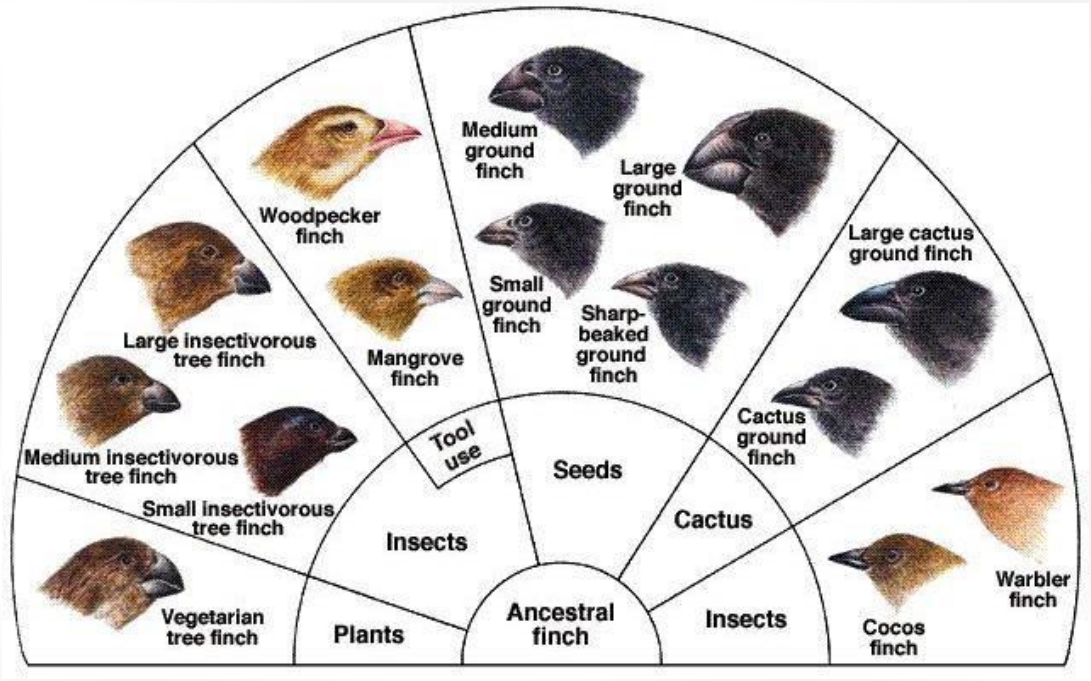


Figure 1.12 Darwin's Theory of Finches on the Galapagos Islands

Basic postulates of Darwinism

A) **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.

B) **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 alllevels of life.

C) **Variation under nature**: No two individuals of a species are exactly similar and they havesome differences. These differences are called variations, which are not possible without evolution. Variations that pass from generation to the next generation give rise to new characters and heredity (inheritance of useful variations).

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

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

Activity 1.5

Dear learner, what types of evidence are commonly used to support Darwin's theory of evolution?

Antibiotic resistance – a modern example of selection in action

Bacteria can develop resistance to antibiotics such as penicillin due to genetic mutations. Once resistant, the antibiotic will not affect the bacteria's ability to grow and reproduce. The fate of the bacterial population after acquiring resistance depends on whether or not they are exposed to the antibiotic again. This is summarizedin Figure 1.13 below.

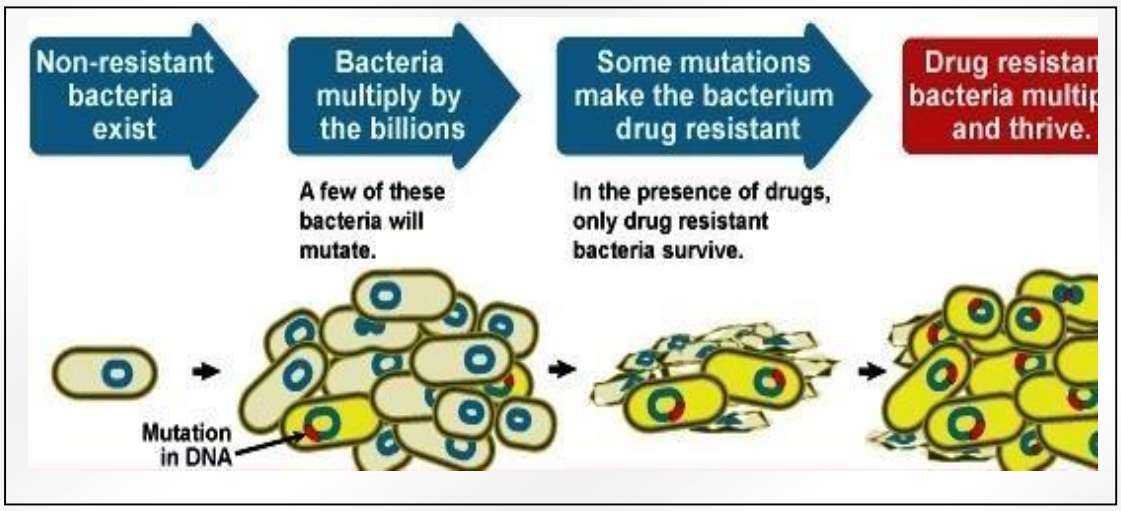


Figure 1.13 Drug resistance in bacteria is often the result of a genetic mutation

1.3.3 Neo-Darwinism theory

What is Neo-Darwinism theory?

Dear learner, it's interesting to note that when Charles Darwin wrote his book "On the Origin of Species", he had a limited understanding of genetics since Gregor Mendel had not yet conducted his groundbreaking research on inheritance. However, our current knowledge of genes and their actions can now be integrated into the theory of natural selection to give us a better understanding of the driving forces behind evolution.

Keyword

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

Genes determine the characteristics of organisms, but when we consider how a population might evolve into a new species, we need to think not just in terms of the alleles that each individual might carry, but also in terms of all the alleles (all the genes) available in the population. This collection of genes in a population is known as the gene pool. Neo-Darwinism is a modified version of the theory of natural selection that reconciles Darwin's and Hugo de Vries' theories. Scientists who contributed to this theory are Huxley and R.A. Fischer.Postulates of the Neo-Darwinism are:

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

Self-evaluation checklist

Put a tick (✓) against each of the following tasks which you can perform.

- Can you elaborate the differences and similarities of Lamarck and Darwin theory of evolution ☐
- Lamarck theory of evolution is explained by inheritance of acquired characters ☐
- Do you agree that Darwin explained theory of evolution based on natural selection ☐

Self-test exercise

Choose the correct answer

1. Which one of the following condition can be best explained by Lamarckism?

A. How giraffes got their long neck

B. How humans lost their tail

C. How humans became bipedal

D. All of the above

2. Which of the following is NOT 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

3. One of the following is NOT part of postulates of Neodarwinism.

A. Genetic variability

B. Natural selection

C. Reproductive isolation

D. Inheritance of acquired traits

4. Which one of the following is correct about Darwin’s Natural selection theory?

A. Organisms produce more offspring to survive in their environment.

B. Individuals that are better physically fit to survive grow, mature and reproduce.

C. Individuals that lack fitness do not reach to an age of maturity nor do they produce fewer offspring.

D. None

5. In comparing Darwin’s theory of evolution with Lamarck’s, it is true to say that:

A. Darwin based his theory on natural selection whilst Lamarck based his on use and disuse

B. Lamarck believed that variation arose out of a need to change whereas Darwin suggested that variations were already present in populations

C. Both suggested that new species could evolve eventually

D. all of the above

6. Although now discredited, Lamarck’s work is regarded as important because he attempted to explain:

A. how natural selection plays vital role for evolution

B. how an individual could acquire new characteristics

C. how a gene pool could change over time

D. how mutations could appear

7. Darwin's theory of natural selection was based on the observations that:

A. all things tend to over-reproduce and there is a struggle for existence

B. there is variation in populations and there is a struggle for existence

C. all things tend to over-reproduce and there is is no struggle for existence

D. all

8. Darwin's finches were able to evolve into different species from one ancestral type because:

A. there were many different habitats and niches on the Galapagos islands

B. there was variation in the population of ancestral finches that colonised the islands

C. there was little competition for the niches

D. all of the above

9.The occurrence of vestigial organs on the basis of Lamarck's theory explains

A. continuous and frequent use of an organ, generation after generation becomes more developed

B. frequent use of an organ generation after generation will come to extinct

C. variation in populations and struggle for existence

D. None

10. A combined natural selection theory, genetic theory and theories about animal behavior best explained by

A. Darwinism theory

B. Lamarck theory

C. Neo-Darwinism theory

D. All

Section 1.4 The evidence for evolution

Dear learner, in this section, you will be able to:

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

What are the main evidences for evolution?

Dear learner, having delved into the intriguing theories of evolution, you are now in an exciting journey through the compelling evidence that supports evolution.

1.4.1 Comparative anatomy

Explain in detail how comparative anatomy provides evidence for evolution?

❁ Dear learner, if you interested in learning more about evolution, you might want to explore the concept of comparative anatomy. **Comparative anatomy** is a powerful tool for understanding the relationships between different species and their evolutionary history. Scientists use this method to study the similarities and differences in the physical structures of organisms, such as bones, organs, and tissues, and use this information to uncover their possible evolutionary relationships. One of the key assumptions of comparative anatomy is that organisms with similar anatomical features are more closely related to each other than organisms with different features. This is because these similarities are likely to have arisen through common ancestry. For example, the forelimbs of mammals share many similarities in their bone structure, suggesting that they are all descended from a common ancestor with similar forelimbs. Another important aspect of comparative anatomy is the study of homologous structures. These are structures that look similar but have different functions. **Homologous structures** are thought to be evidence of a shared evolutionary history between species. For example, the wings of birds and the arms of humans have a similar bone structure, even though they have different functions. This suggests that birds and humans are closely related and share a common ancestor with this type of limb

Keyword:

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

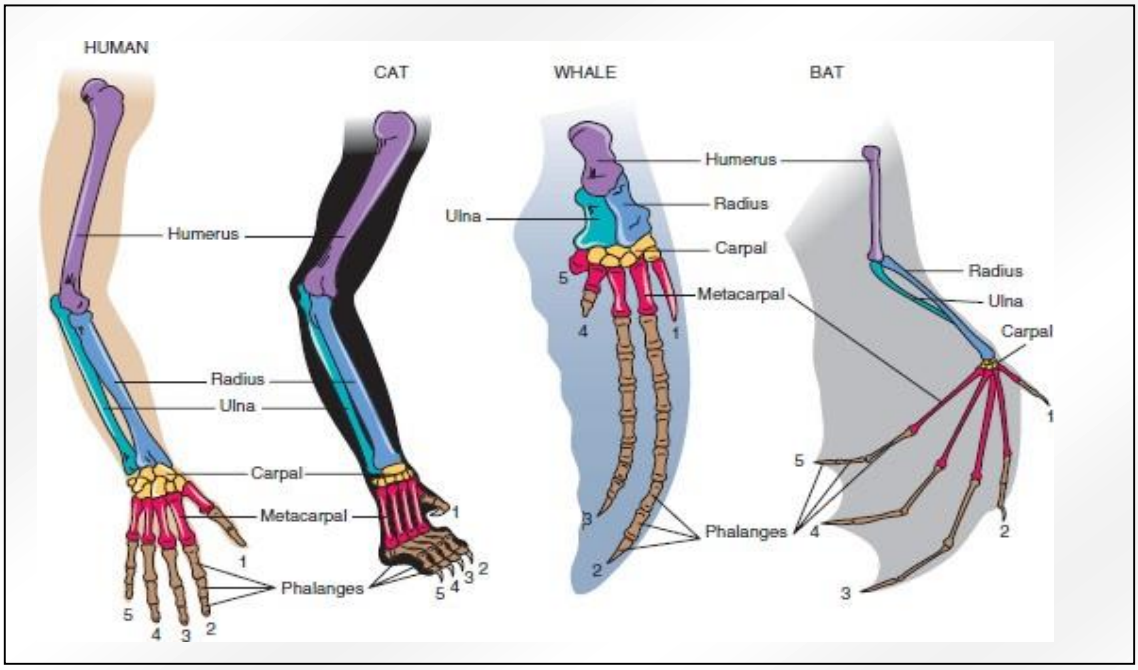


Figure 1.14 The homologous forelimbs of mammals.

Upon close examination, the forelimbs of humans, whales, cats, and bats have very similar structures but different functions (refer to Figure 1.14). 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 manipulating in humans
- leg for running in cats
- flipper for swimming in whales
- wing for flying in bats

Keywords

Pentadactyl limb *is a limb with five digits*

Analogousstructures *struactures havingthe same function but different anatomy and different evolutionary origin.*

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 descended from that original type, which they share a common ancestor with. However, comparative anatomy needs to be used carefully as evidence for evolution. This is because while some organisms have structures that function in very similar ways,

morphologically and developmentally these structures are very different. We call these analogous structures.

Activity 1.6

Dear learner, in what ways do homologous structures differ from analogous structures?

Even though analogus structures have the same function, they cannot indicate that two species share a common ancestor because they are so different structurally. Although, all the wings of a bat, bird and mosquito serve the same function, their anatomies are very different. For example, the wing of a bird has bones inside and is covered with feathers while the wing of an insect has neither of these (See Figure 1.15). They are analogous structures that have evolved separately.

Figure 1.15 Analogy in animals

1.4.2 Embryology

Explain in detail how comparative embryology provides evidence for evolution.

Dear learner, **comparative embryology** studies the development of vertebrate embryos before hatching or birth, revealing similarities that suggest a common ancestry.

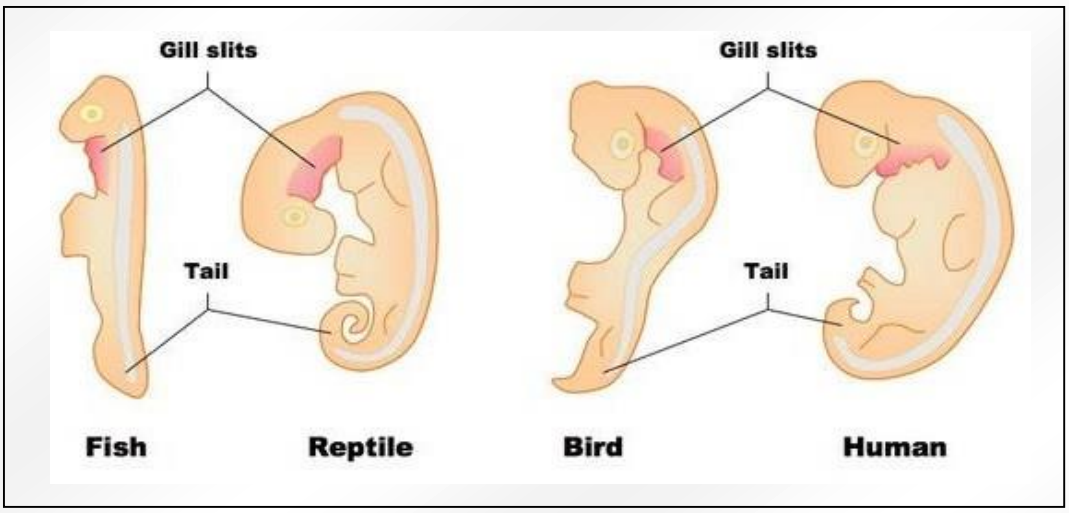


Figure 1.16 Similarities in development of embryos.

During early development, gill slits and tails are present in all vertebrate embryos (See Figure 1.16).. These 'gill slits' are not actual gills, but in some species, they disappear later in embryonic development, while in fish and larval amphibians, they contribute to the development of gills. The embryonic tail does not develop into a tail in all species and 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.

Activity 1.7

Dear learner, have you considered that during embryogenesis an embryo retraces its evolutionary history?

1.4.3 Palaeontology

Explain in detail what palaeontology is how it provides evidence for evolution?

Dear learner, the scientific study of fossils is known as **palaeontology**. Fossils are the remains of organisms that became embedded in soil or water and were preserved for many hundreds of years. These remains can appear as skeletal structures, footprints, molds, or intact structures. By studying fossils, we can establish similarities between organisms in the present and their ancestors in the past. These similarities can provide evidence of common origins between different closely related animals, while differences can help us understand how they have evolved and why. Fossils are incredibly important evidence for proving the theory of evolution and detecting common ancestry. We can group fossils into two main 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.

Figure 1.17 A spider preserved in amber

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)

Dear learner, type I fossils can be the actual organism or part of an organism, such as a piece of bone or hair or feather as it actually was. For example, this spider (See Figure 1.17) has been trapped, completely unchanged, inside the amber for millions of years. Amber is fossilized resin from trees. This spider probably

became stuck inside the sticky resin and could not escape. As the amber became fossilized, the spiderwas protected from micro-organisms and the air which would have led to its decomposition. In many fossils like this, the softparts of the body have been lost, but the exoskeleton is perfectly preserved. In some cases, however, the entire body remains.

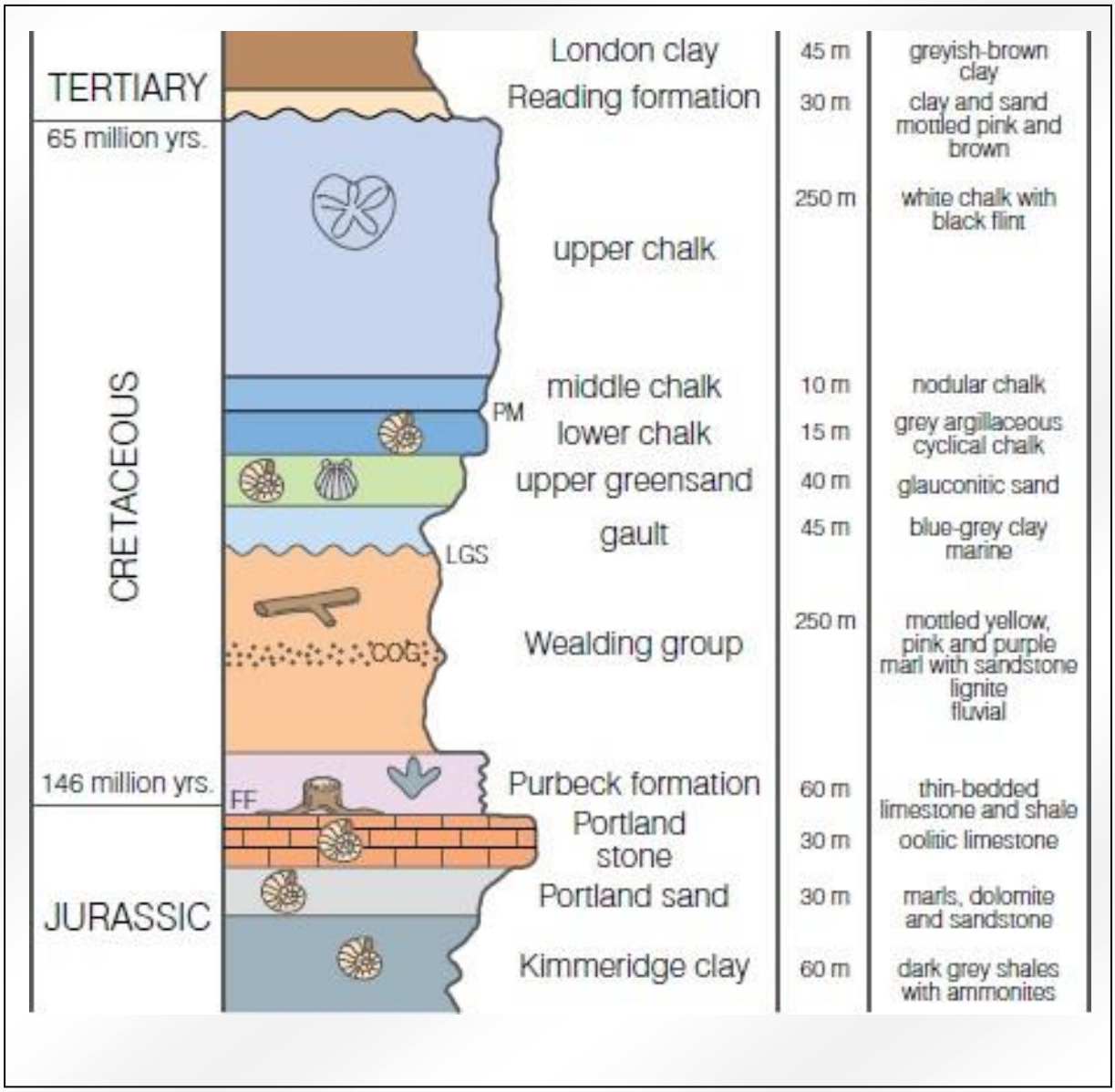
Activity 1.8

Dear learner, would you be able to provide an explanation of the fossil formation process?

Dating fossils

Dear learner, can you explain what stratigraphy is?

Sedimentary rocks are formed in layers known as strata, which provide valuable information about the changes in organisms over time. This field of study is called stratigraphy. The oldest fossils and strata are located in the lower layers, while the more recent ones are found in the upper layers closer to the surface. In Figure 1.18, the sequence of strata in southern England is depicted. The depth of the strata corresponds to their age, and the thickness of each layer in the diagram indicates the duration of its formation. The terms 'Tertiary', 'Cretaceous', and 'Jurassic' refer to specific geological time periods. Certain minerals and organic matter, such as wood, bones, and shells, can contain radioactive isotopes. By measuring the proportions of parent and daughter isotopes in a sample, scientists can determine its age using a method called radiometric dating. The half-life of a radioactive isotope is the time it takes for half of the parent isotopes to decay into daughter isotopes, as illustrated in Figure 1.19



. **Figure 1. 18** Stratigraphy and the relative age of fossils.

Activity 1.9

Dear learner, have you explored how scientists determine the age of rocks through various methods? Specifically, how do they ascertain the age of each geological layer? Additionally, have you come across the concept of half-life time in the context of rock dating methods?

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 by establishing the age of one thing as older as or younger than another.

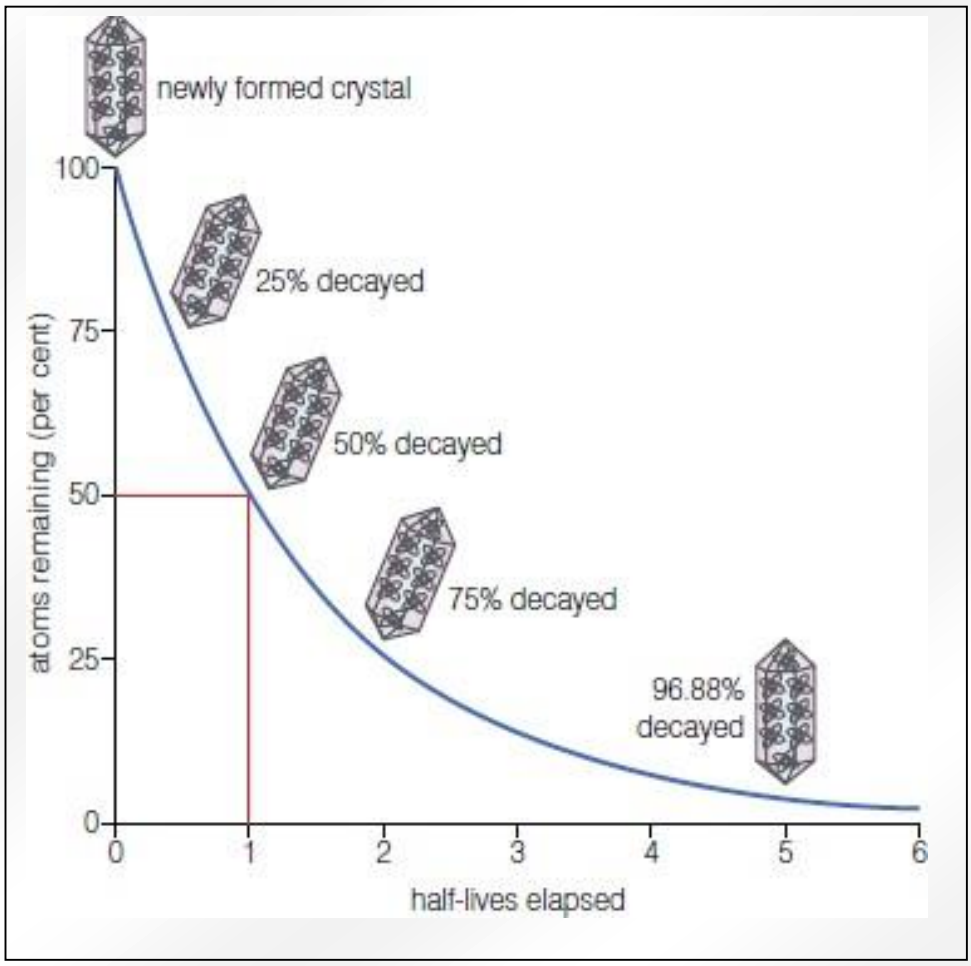


Figure 1.19 Half-life of a radioactive element

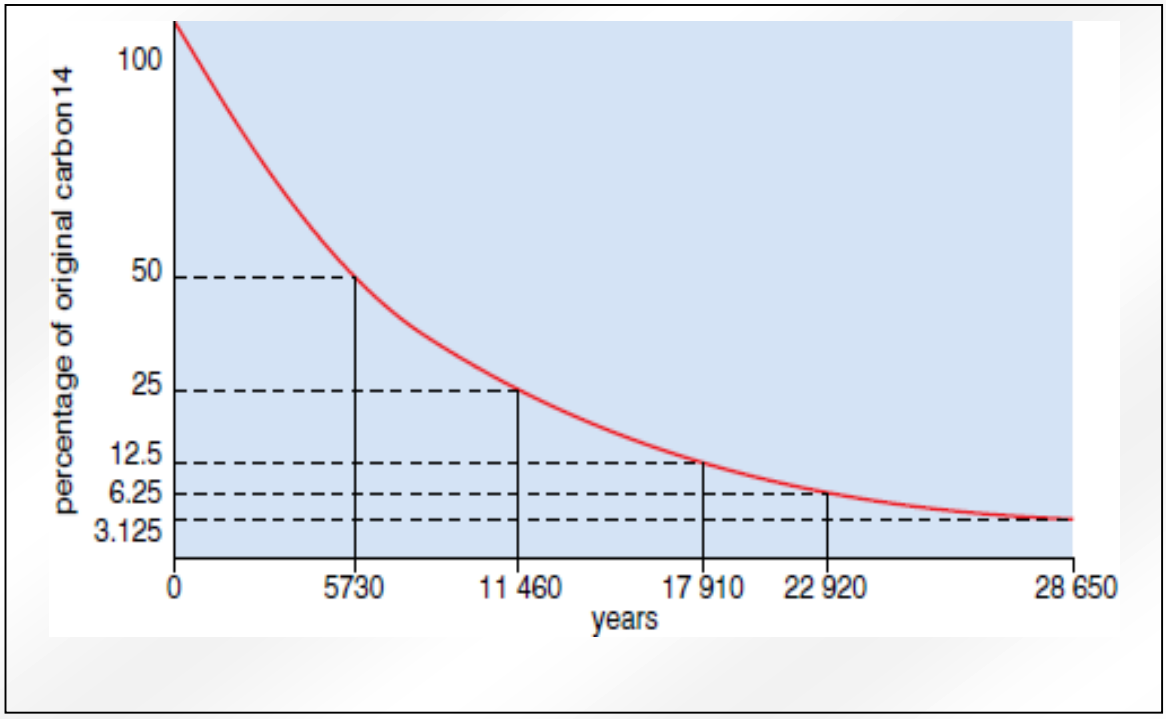


Figure 1.20 Converting the percentage of carbon 14 in a fossil to an age.

Dear distance learner, could you please explain the methods used by scientists to determine the age of rocks and how they ascertain the age of each individual layer?

Dear learner, scientists use one of the two techniques to date rocks:

- Radiocarbon dating, or
- Potassium–argon dating.

Both techniques rely on the principle that radioactive atoms decay into other atoms overtime. Radioactive carbon atoms (C14) decay into non-radioactive nitrogen atoms (N).

Radioactive potassium atoms (K40) decay into argon atoms (A40). Each has what is knownas a **half-life**. During this period, half of the radioactive atoms decay. So, starting with a certain number of radioactive potassium atoms, 50% of the radioactive will still be radioactive after one half-life. After a second half-life, 50% of this will be decayed and 25% of the originalnumber will still be radioactive.

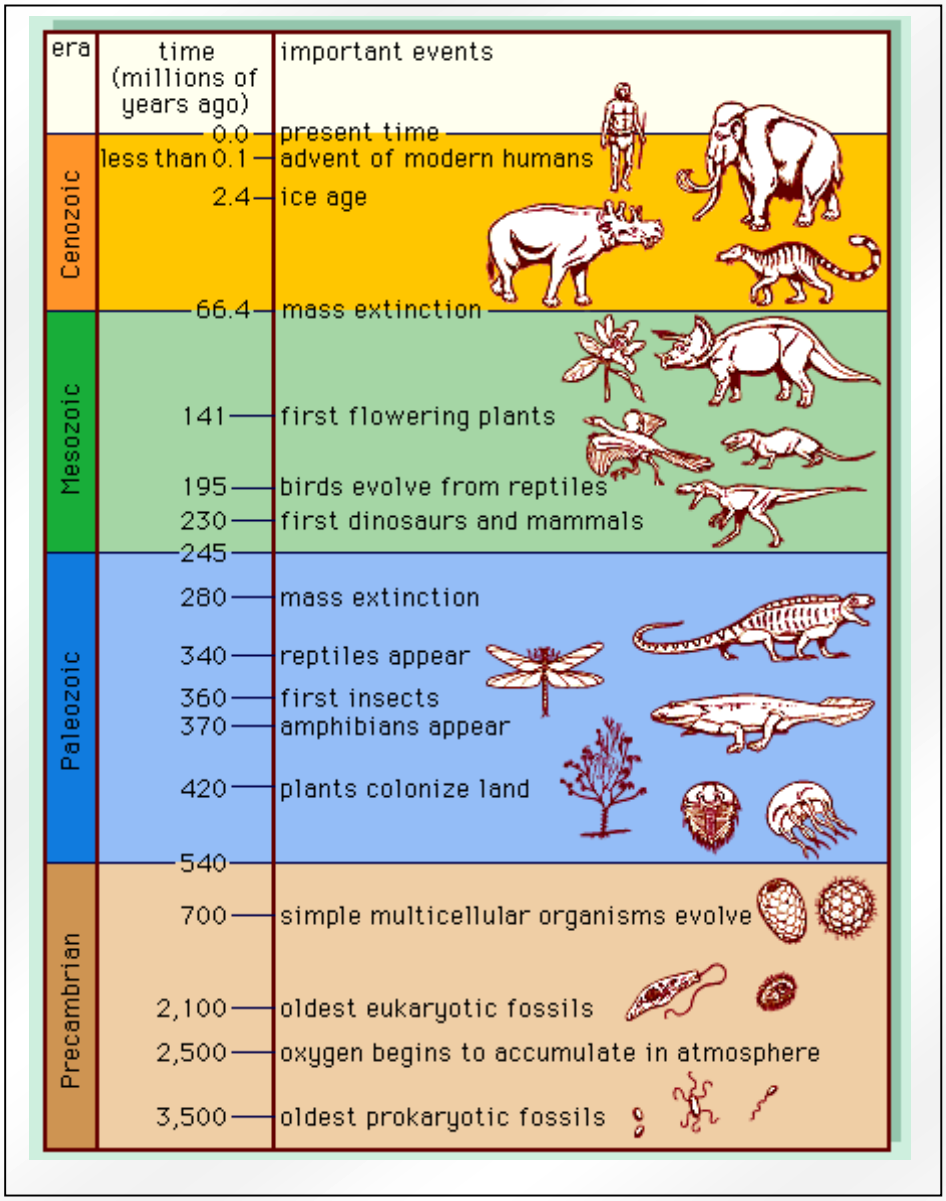


Figure 1.21 Key events in the fossil record of animal evolution

1.4.4 Biochemistry

Dear learner, organisms that have very similar **molecules and biochemical pathways** are considered to be closely related evolutionarily. Some of the chemicals used in such analysis are DNA and haemoglobin, among others. Species that are closely related are believed to have the most similar DNA and proteins. Conversely, those that are distantly related are thought to share fewer similarities. For instance, when we compare DNA sequences, we find that 98% of our DNA is the same as that of chimpanzees, which confirms that chimpanzees are the closest relatives of humans

(refer to Figure 1.22). To determine the similarity between the DNA of two different species, we use a technique called DNA hybridization. This technique measures the extent to which a strand of DNA from one species can hybridize with a strand of DNA from another species. In this technique, the double helix of the DNA molecule is heated to separate it into single strands. After that, the single-stranded DNA (ssDNA) from both species is mixed, and the mixture is cooled. Although the ssDNA from species A and species B will hybridize (bind) as it cools, it will not do so along its entire length. If there are mismatched regions (the base pairs are not complementary), they do not bind. However, various techniques are available to measure the percentage of such mismatching. The information can then be used to calculate the percentage similarity of the DNA samples.

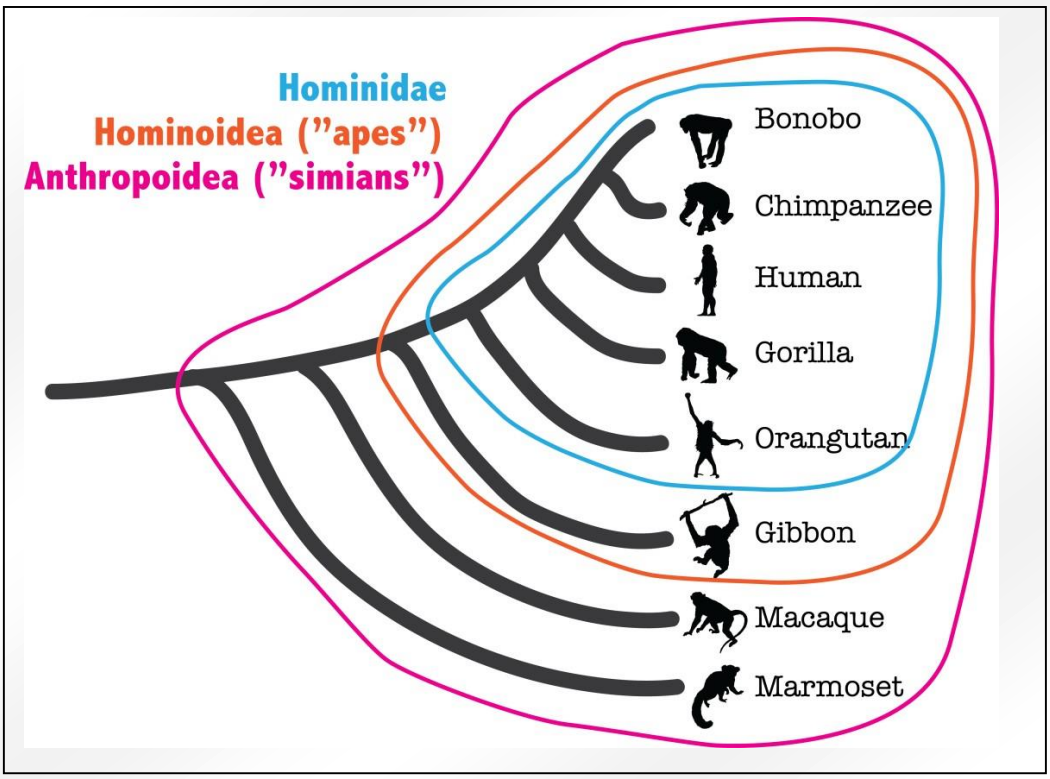


Figure 1.22 A phylogenetic (evolutionary) tree of some animals based on differences in DNA.

Although the **haemoglobin** molecule is similar across all animals that possess it, there are some differences. For instance, the haemoglobin of the lamprey, which is a primitive fish-like animal, has only one polypeptide chain, while most animals, including humans, have

Keyword

Haemoglobin *is the molecule found in red bloodcells that carries oxygen to where it is needed*

haemoglobin with four chains. However, the chains do vary among different animals. Figure 1.23 illustrates the differences in the amino acid sequences of the α chains of haemoglobin in humans and several other animals. This diagram is presented to demonstrate how different animals might have diverged from the evolutionary line that led to humans.

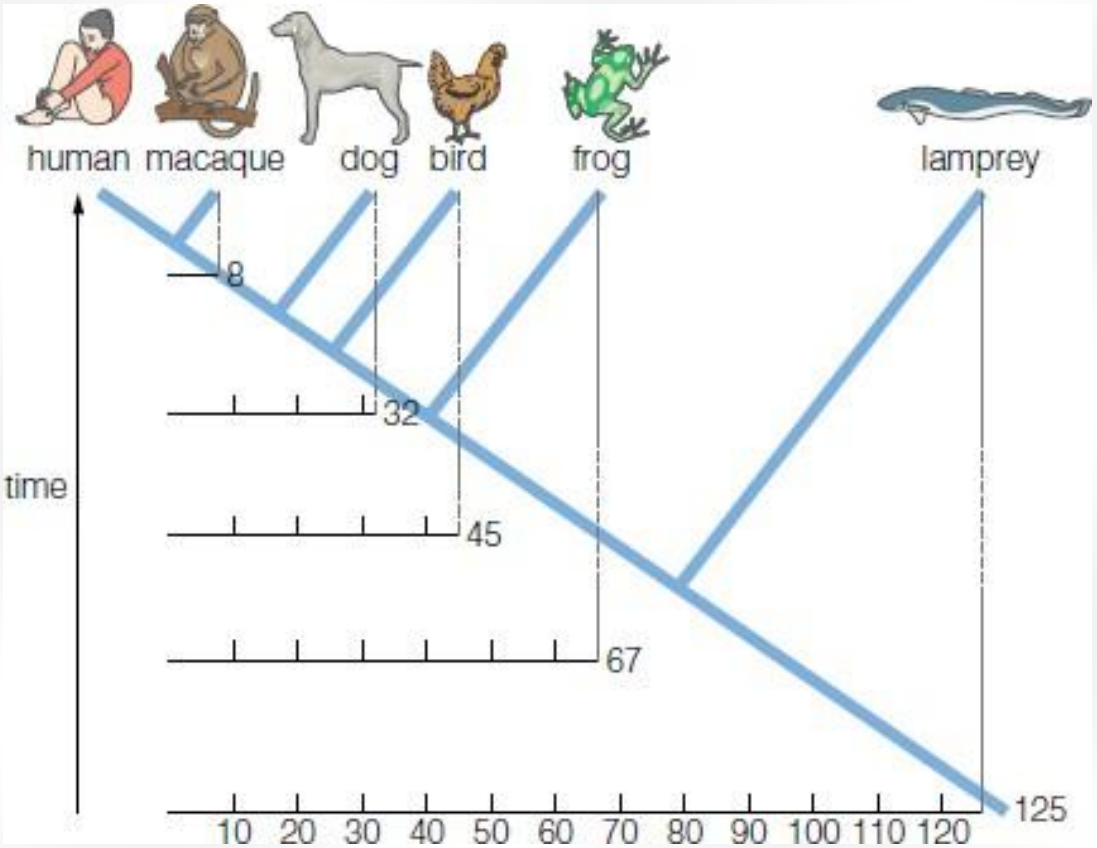


Figure 1.23 The evolutionary relationships of some animals shown by differences in haemoglobin

Molecules commonly shared among organisms are used to show evolutionary relationships. However, haemoglobin analysis cannot be used for plants and algae in phylogenetic trees.

Self-evaluation checklist

Put a tick (✓) against each of the following tasks which you can perform

Dear learner, can you explain the following how they provide evidence for evolution?

- comparative anatomy ☐

- embryology
- fossil records
- biochemistry

🛠 Self-test exercise

Choose the best answer

1. Example of a homologous organ
   A. The arm of a human, wing of a bird
   B. Wing of an insect, wing of a bird
   C. Leg of a dog, leg of a spider
   D. None of the above
2. The wing of the bat and the fore-limb of the dog are said to be homologous structures. This indicates that:
   A. They have the same function
   B. They have common ancestry
   C. They have a different ancestry
   D. all
3. The Study of fossils is

   A. Herpetology B. Serology C. Palaeontology D. Homology
4. Which of the following are homologous organs?
   A. Wings of a bird and hands of a human
   B. Wings of a bird and wings of an insect
   C. Wings of a bat and wings of a bird
   D. all
5. Which of the following are analogous organs?
   A. Wings of a bird and hands of a human
   B. Wings of a bird and wings of an insect
   C. Wings of a bat and wings of a bird
   D. B and C
6. A comparison of DNA sequences shows that 98% of human DNA is the same as chimpanzees DNA is best example for one of the following evidences of evolution
   A. Palaeontology
   B. Biochemistry
   C. Comparative anatomy
   D. Embryology

7. Similarities in early development of embryos is an evidence of evolution explained by

A. Palaeontology

B. Biochemistry

C. Comparative anatomy

D. Embryology

8. Studying fossils and trying to establish similarities between organisms in the present to its ancestor in the past is

A. Palaeontology

B. Biochemistry

C. Comparative anatomy

D. Embryology

9. Fossils age can be determined using

A. absolute dating

B. relative dating

C. half-life time

D. A and B

10. The amount of time it takes for half of the parent isotopes to decay into daughter isotopes is

A. Palaeontology

B. absolute dating

C. relative dating

D. half-life time

Section 1.5 Natural selection

Dear learner, in this section you will be able to:

- Define natural selection
- Describe the types of natural selection with examples
- Apply the theory of natural selection in the day-to-day life (survival of thefittest)
- Appreciate the struggle among organisms for survival

Dear learner, having gathered a wealth of evidence supporting evolution, next you will learn about of natural selection

What is natural selection? How natural selection leads to formation of different species?

Dear learner**, natural selection** is the 'driving force' behind evolution. It is the process that brings changes (over time) in populations that can, eventually, lead 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 do. They will pass on their advantageous alleles to their offspring and, in successive generations, the frequency of thesealleles will increase in their gene pool. The advantageous types will, therefore, increase in frequencyin successive generations.

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 fromchimpanzees. But, the different races of humans are all members of the same species. Why?

Speciation

Dear learner, the definition of species is, a group of similar organisms that can interbreed to produce fertile offspring with a similarbiochemistry, physiology and evolutionary history. This explains why all humans are members of the same species, but they belong to a different species from 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

- **directional selection**
- **stabilizing selection and**
- **disruptive selection**

Directional selection

Dear learner, the following example is how directional selection operates in animals. Individuals at one extreme could have a disadvantage whereas those at the other extreme

have an advantage. For example, thicker fur (longer hair) in foxes is an advantage in a cold climate. Thinner fur (short hair) in foxes is an advantage in a hot climate. If the environment changed from hot to significantly colder, or a group of foxes were to establish in a new, colder environment, then there would be a selection pressure in favour of the foxes with long fur against those with short fur. Over time, the frequency of the alleles causing longer fur will increase.

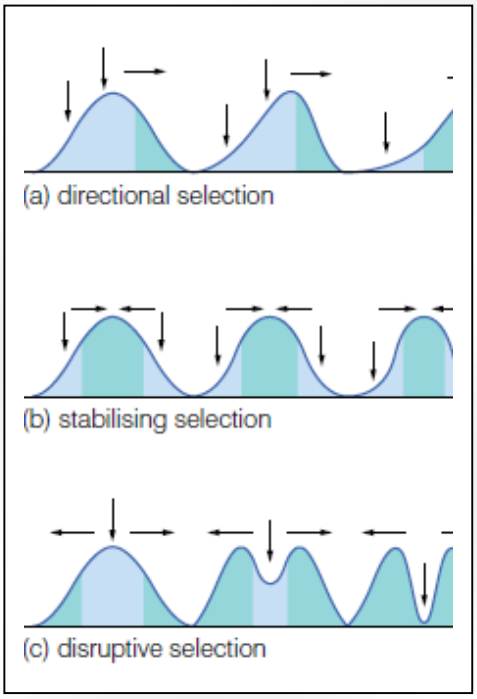


Figure 1.24. A summary of the different types of natural selection

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.*

Explain the similarities and differences between allopatric and sympatric speciation?

Dear learner, 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?

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 anumber of ways in which this can occur. The two main ways are: **Allopatric speciation and Sympatric speciation.** As long as two populations are able to interbreed, they are unlikely to evolve into distinct species. They must some how go through a period when they are prevented from interbreeding. Both allopatric and sympatric speciation involves isolating mechanismsthat prevent different populations from interbreeding for a period of some time (See Figure 1.25). 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'.

Activity 1.10

Dear learner**,** explore allopatric and sympatric speciation by consulting various books and reputable sources,

What is polyploidy and why is it important in plant evolution?

Dear learner, poly- means many.

Polyploid cells have many sets of chromosomes per cell – sometimes foursets, sometimes eight or more. Some human liver cells have 92 chromosomes per cell – they are **tetraploid** and have four sets of chromosomes per cell.

Keywords

Polyploidy *occurs when an organism has more than twosets of homologous chromosomes*

Tetraploid: *a tetraploid organism has four sets of homologous chromosomes*

Polyploidy has been important in plant

evolution because it has allowed infertile hybrids to become fertile. When different species form hybrids, the hybrid often cannot produce offspring because all the chromosomes cannot form bivalents (homologous pairs) in meiosis. So, they cannot form sex cells and can't 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 by which the hybrid is now fertile.

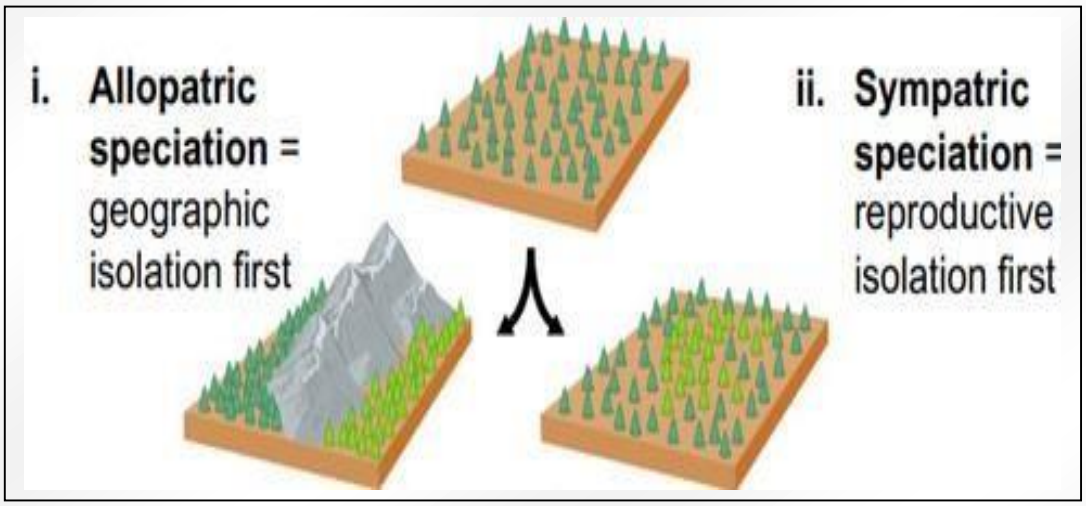


Figure 1.25 Allopatric and sympatric speciation

Compare and contrast divergent and convergent evolution?

Divergent, convergent, and parallel evolution

Dear learner, evolution over time can follow several different patterns. Factors such as environment and predationpressures can have different effects on the ways in which species are exposed to evolve. Thereare three main types of evolution: ***divergent,convergent***, and ***parallel*** evolution (See Figure 1.26).

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.

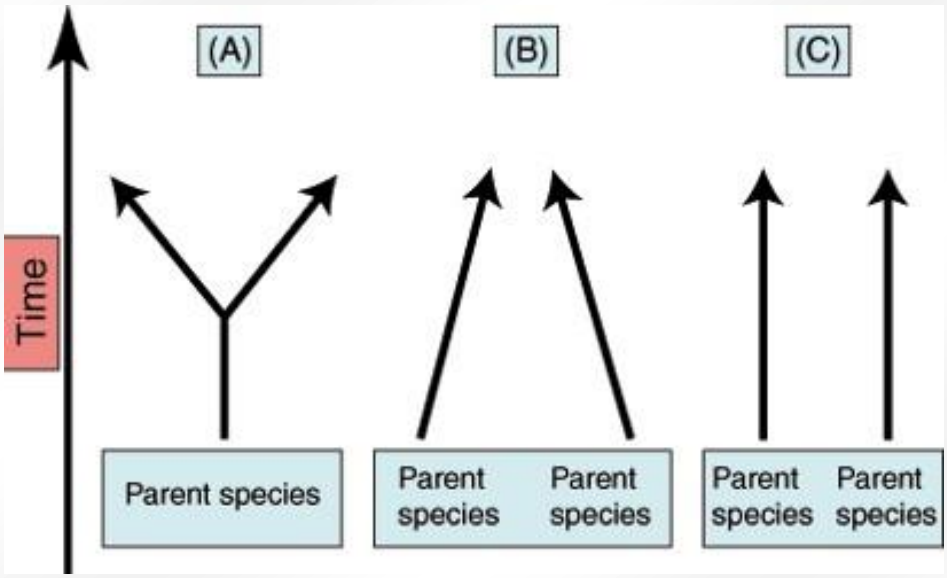


Figure 1.26 Types of evolution; A) Divergent B) Convergent C) Parallel

Convergent Evolution

Convergent evolution causes difficulties in fields of study such as comparative anatomy. 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.

☑ Self-evaluation checklist

Put a tick (✓) against each of the following tasks which you can perform

- Can you define natural selection ☐
- Can you describe the types of natural selection with their examples ☐
- Can you describe the main types evolution ☐
- Can you describe the difference between allopatric speciation and sympatric speciation ☐

🛠 Self-test exercise

Choose the correct answer

1. Allopatric speciation involves:
   A. a period when individuals of two populations are prevented from interbreeding
   B. geographical isolation
   C. a period of increasing genetic diversity of two populations
   D. all of the above
2. In directional selection, the selection pressure operates:
   A. in favour of those individuals showing the mean values for a feature
   B. in favour of those individuals at one extreme of the range of values for a feature
   C. in favour of those individuals at both extremes of the range of values for a feature
   D. none of the above
3. Sympatric speciation involves:
   A. a period when individuals of two populations are prevented from interbreeding
   B. geographical isolation
   C. a period of decreasing genetic diversity of two populations
   D. all of the above
4. Convergent evolution can occur when:
   A. different organisms inhabit different environments
   B. different organisms inhabit similar environments
   C. similar organisms inhabit similar environments
   D. similar organisms inhabit different environments
5. In sympatric speciation, the isolating mechanism could be:
   A. temporal
   B. seasonal
   C. behavioural
   D. any of the above

6. Species occurring in different geographical area are called as

E. Sympatric C. Sibling

A. Allopatric D. Neopatric

7. Which one of the following includes all the others?

A. Natural selection

B. Disruptive selection

C. Directional selection

D. Stabilizing selection

8. A bell shaped curve in a variable indicates which kind selection?

A. Stabilizing selection C. Divergent selection

B. Unidirectional selection D. Disruptive selection

9. Which of the following is most important for speciation?

A. Seasonal isolation C. Behavioral isolation

B. Reproductive isolation D. Tropical isolation

10. Similarities in organism with different genotype indicates

A. Microevolution C. Convergent evolution

B. Macroevolution D. Divergent evolution

Section 1.6 Human evolution

In this section, you will be able to:

- Outline human evolution.
- State the role of paleontological discoveries in Ethiopia in explaining human evolution e.g. Lucy (*Australopithecus afarensis*).

Dear learner, in the previous section you have gained knowledge about natural selection, and the different types of natural selection and types of evolution. In this section you will learn important aspects of human evolution.

 Who are we and where have we come from?

Activity 1.11

Dear learner, how would you describe the complex narrative of human evolution??

Dear learner, there is often a lot of loose language used to describe human evolution. You may hear people say things like "We evolved from monkeys," "We evolved from apes," or "We evolved from chimpanzees." However, none of these statements are entirely accurate. In reality, there has been a "line of evolution" that has been ongoing for millions of years, which has given rise to old-world monkeys, new-world monkeys, great apes, and different species of humans that have lived (refer to Figure 1.27). While we, *Homo sapiens*, are the latest humans to have inhabited the Earth, we are not the only ones.

What features distinguished human from primates?

Dear learner, we have two particular features that distinguish us from other primates. These are:

- A very large brain, and
- Bipedalism – the ability to truly walk on just two legs.

There has been a lot of ongoing debate among biologists about which came first and how exactly the "evolutionary tree" (shown in Figure 1.27) gave rise to various primate groups, including apes and humans. While there are differences in the details, it is generally agreed upon that a line of evolution branched to create the different primate groups, with contemporary humans existing on Earth rather than in a distant past. Figure 1.28 provides a more detailed look at the part of the evolutionary tree that pertains to humans and living great apes

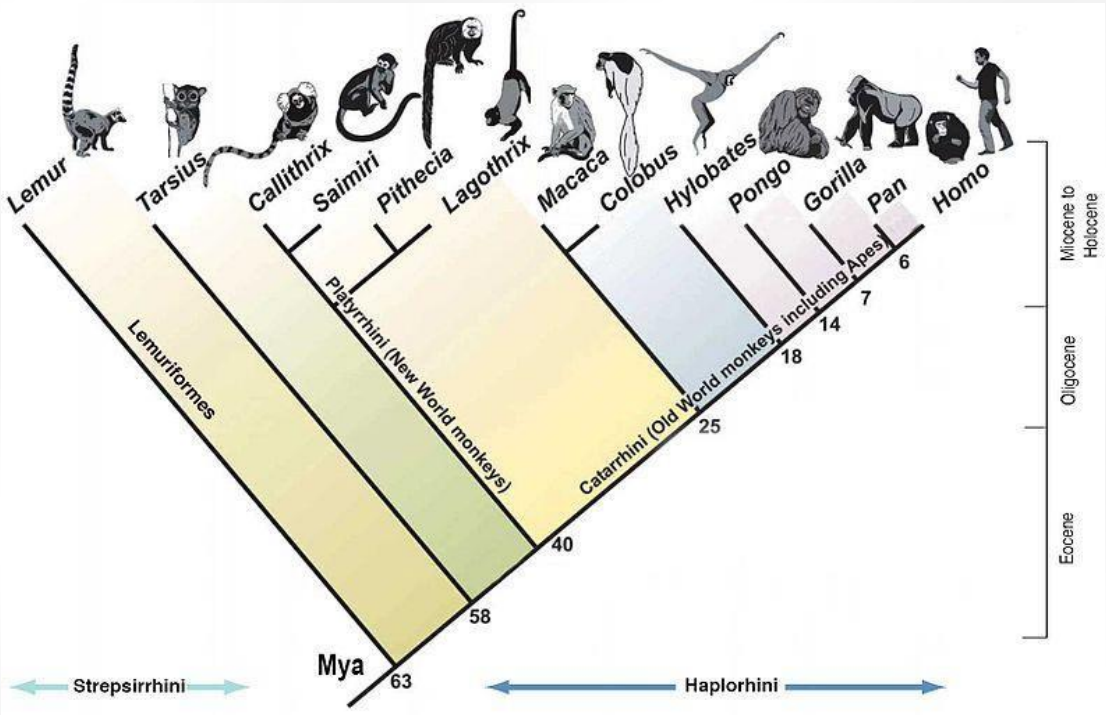


Figure 1.27 The evolutionary tree for modern primates

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

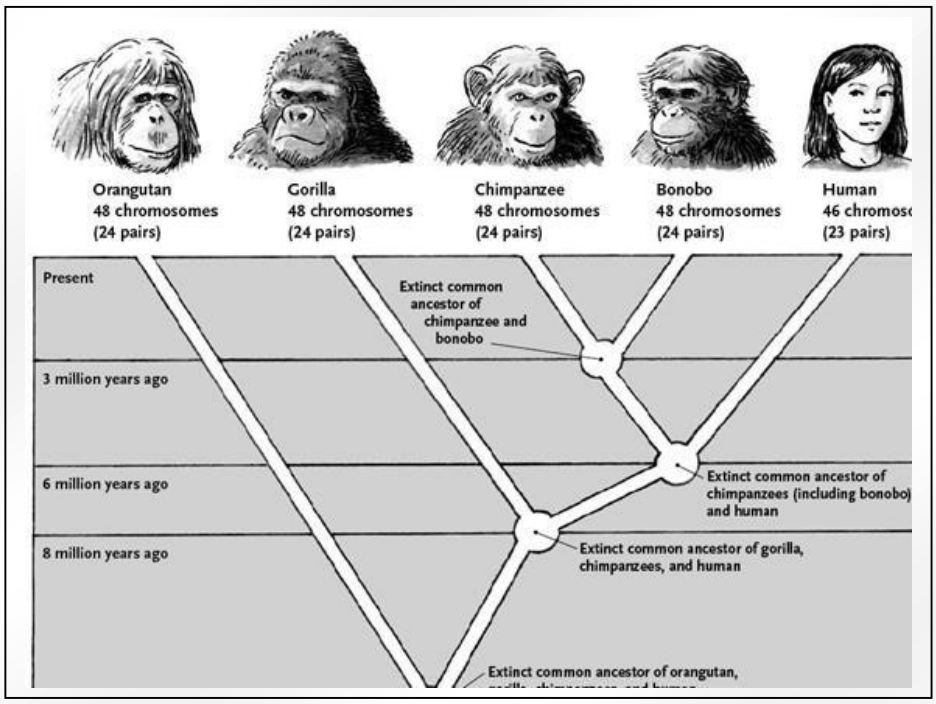


Figure 1.28 The evolutionary tree of humans and the great apes

Branching points in the evolutionary tree represent ancestors (See Figure 1.29). At these points, it is assumed that an ancestral type was divided into at least two populations which subsequently evolved along different lines. For example, both humans and chimpanzees that lived about 6 million years ago evolved from a common ancestor (See Figure 1.28)

So far, we have talked about 'humans' rather than the one specific type of human (ourselves *Homo sapiens*) who now inhabits the planet. There were other humans before us and, there had been humans before them, what we might call 'pre-humans'. However, all humans belong to the **genus** *Homo*.

Figure 1.29 shows a timeline for the major **hominin** and **hominid** species based on the currently available fossil evidence. Looking carefully at Figure 1.29 and Figure 1.30, 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'.

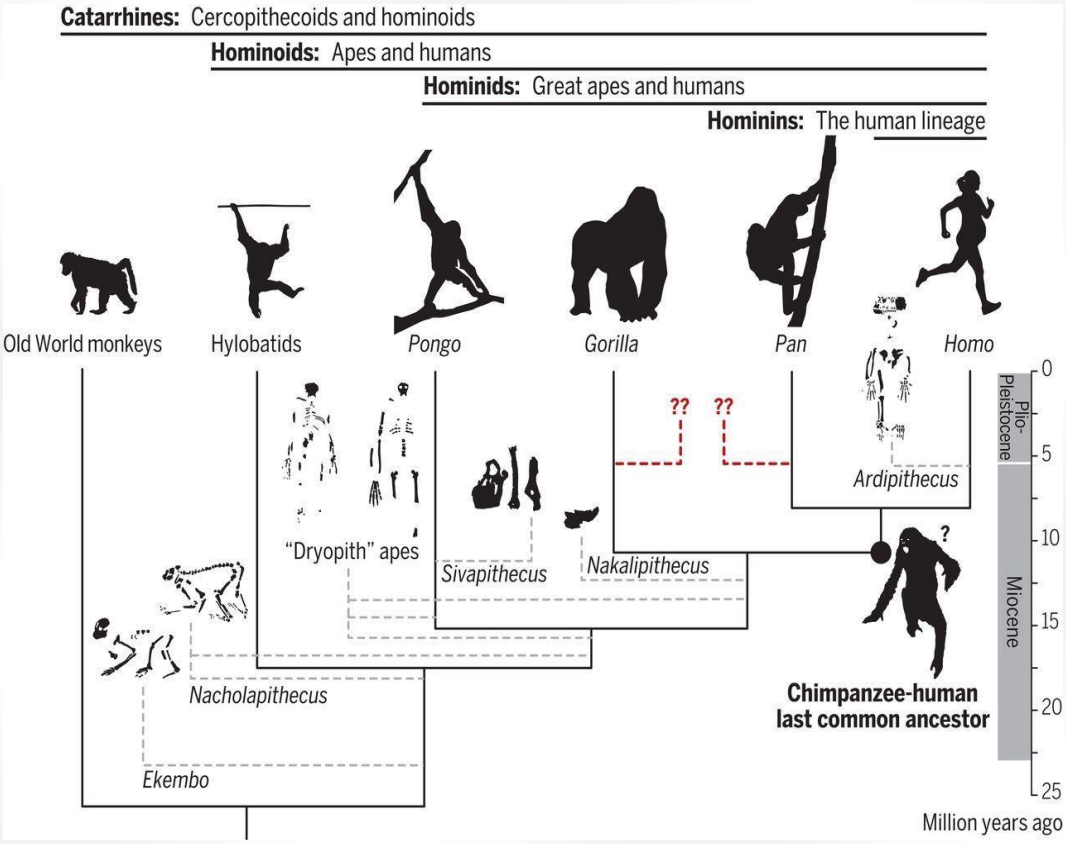


Figure 1.29. A timeline for the fossils of human family

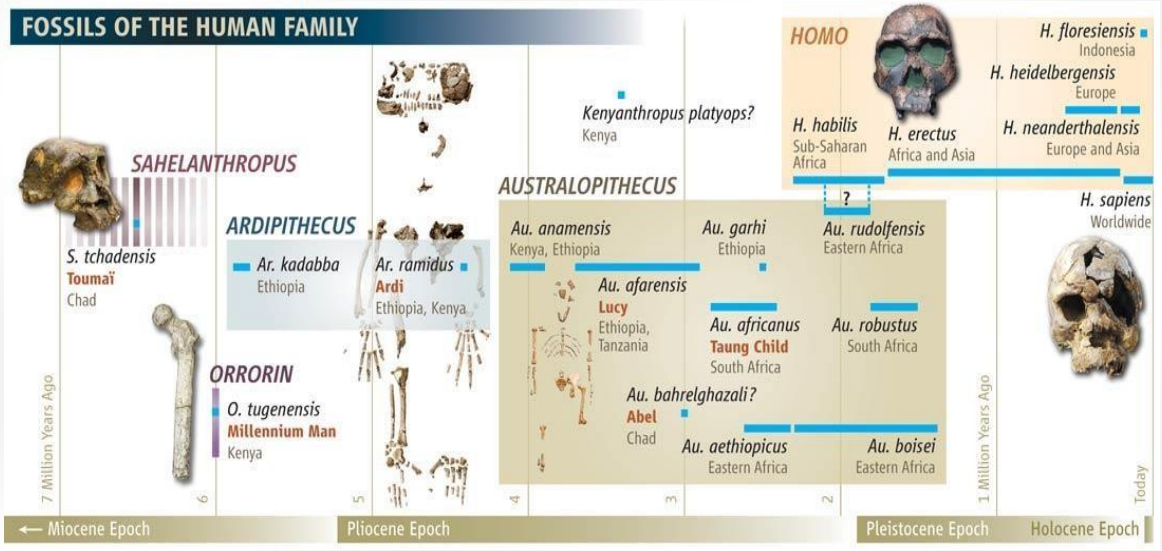


Figure 1.30 A timeline for the major hominin and hominid species

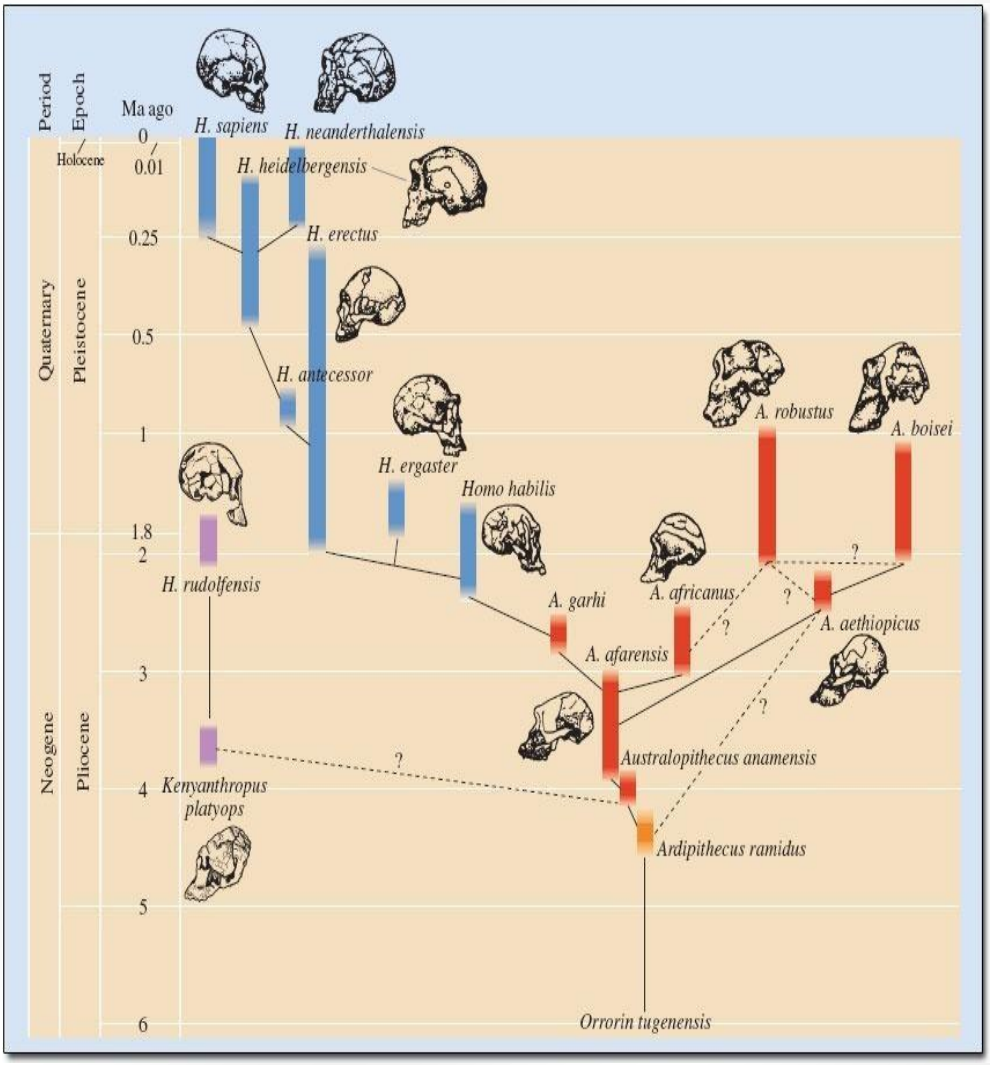


Figure 1.31 A timeline for the fossils of human family

Ardi (*Ardipithecus ramidus*) and Dinkinesh "Lucy" (*Australopithecus afarensis*)

❁ Dear learner, both Dinkinesh (Lucy) and Ardi are important fossils that explain the evolution of modern humans and chimpanzees from a common ancestor. Dinkinesh was discovered by Donald Johansonand Tom Gray in 1974 at Hadar, Ethiopia. Dinkinesh 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) (See Figure 1.32)

However, there is also evidence that Dinkinesh (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.

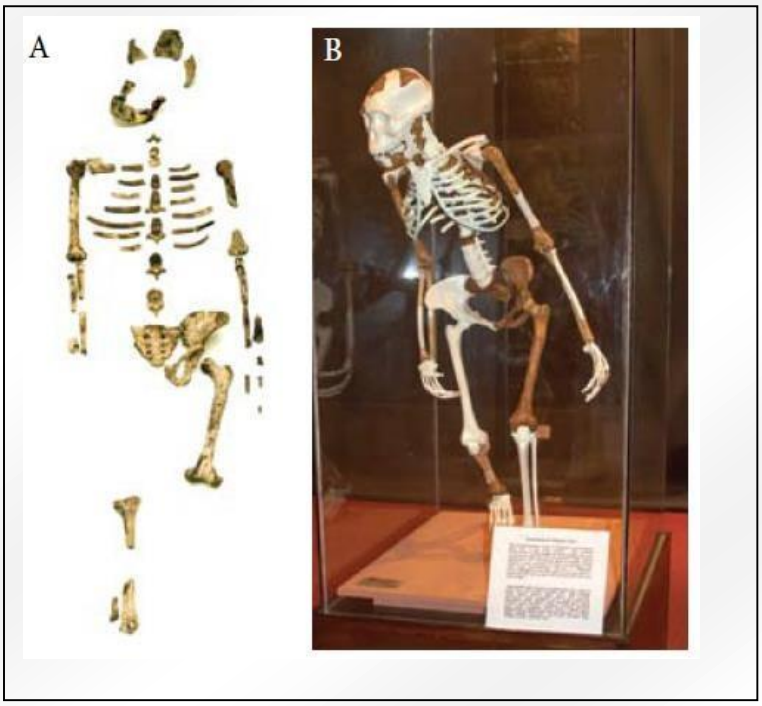


Figure 1.32 A – The original Dinkinesh (Lucy) fossil; B – The Dinkinesh display includingreconstructed parts

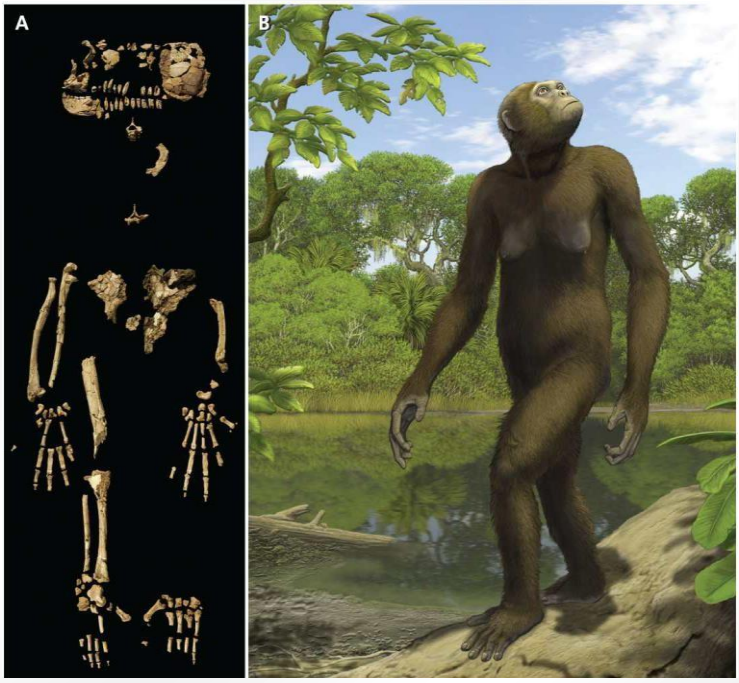


Figure 1.33 A: relatively complete skeleton of *Ardipithecus*, which lived 4.4 million years ago. B: *Ardipithecus* shows signs of being adapted for both bipedalwalking and arboreal life

Dinkinesh had a brain about the same size as that of a chimpanzee, so her discoverywas 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 theAfar dessert in Ethiopia, but research papers were finally published in 2009 after many years of analysis 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 has been the nearest and most recent fossil to the 'common ancestor' of humans and chimpanzees. 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 were signs of being adapted for both bipedal walking and arboreal life (See Figure 1.33).

Activity 1.12

Dear learner Ethiopia holds a pivotal position in the annals of human evolution. We encourage you to explore the significance of pivotal discoveries such as Lucy, Ardi, and Selam by consulting not only the specified textbook but also additional literature and reputable online sources.

How brain size changed during human evolution?

Dear learner, throughout human evolution, the brain has undergone considerable increase in size and complexity. Studies on comparative anatomyof fossils revealed that the cranial capacity has increased with each new hominid species evolved (See Figure 1.34). However, the brain has increased in size as a proportion of body mass. Species of *Australopithecus* have a brain thatis 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 to 8% in the great apes.

Is there any benefit from larger human brain?

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

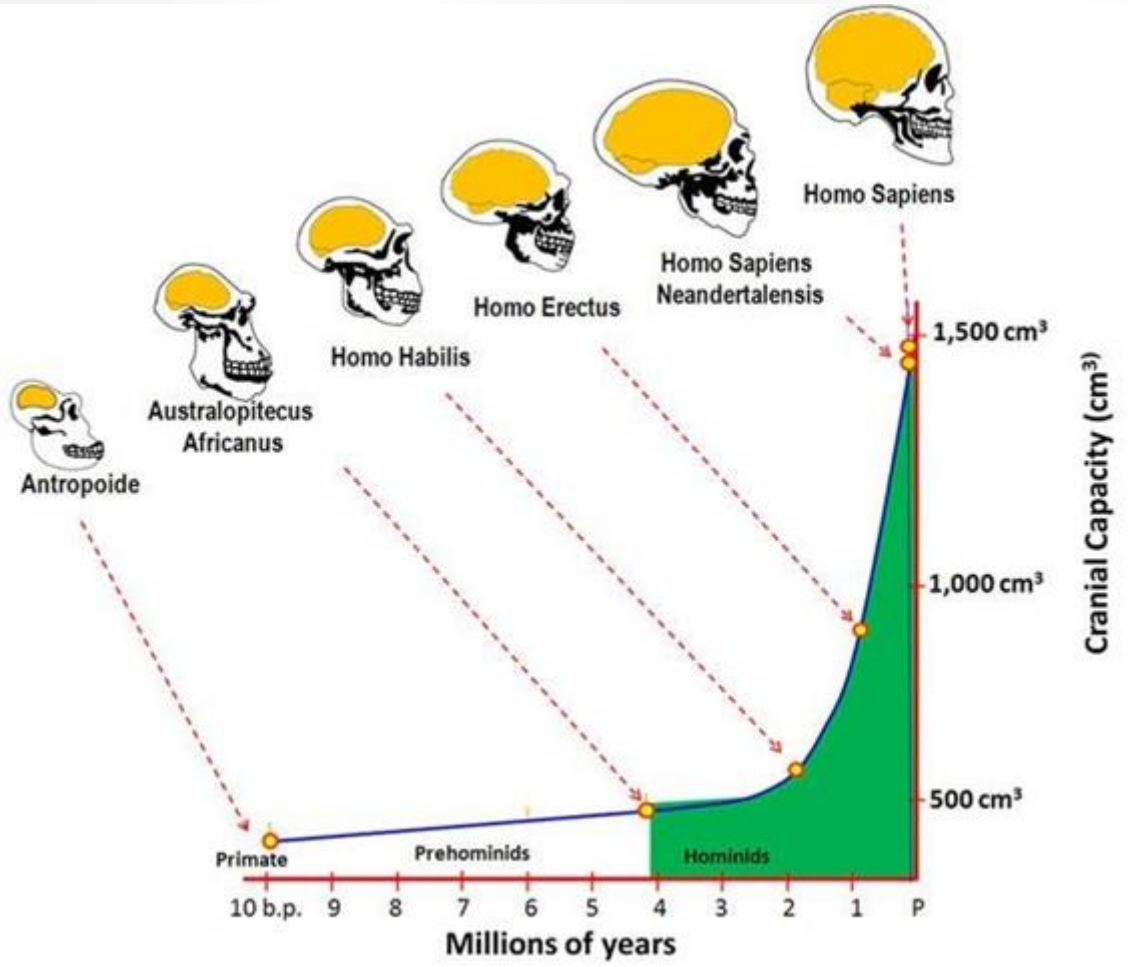


Figure 1.34 Brain size in different hominids

These abilities clearly depend on other physical adaptations such as longer legs, more nimble fingers and a straighter spine where the physical changes would not confer the same advantage without the larger brain to co-ordinate the activities.

Are we still evolving?

Homo sapiens (modern humans) first appeared in Africa and have since migrated to all other parts of the world. Figure 1.35 shows these migratory patterns together with the time

(thousands of years ago) when they took place.

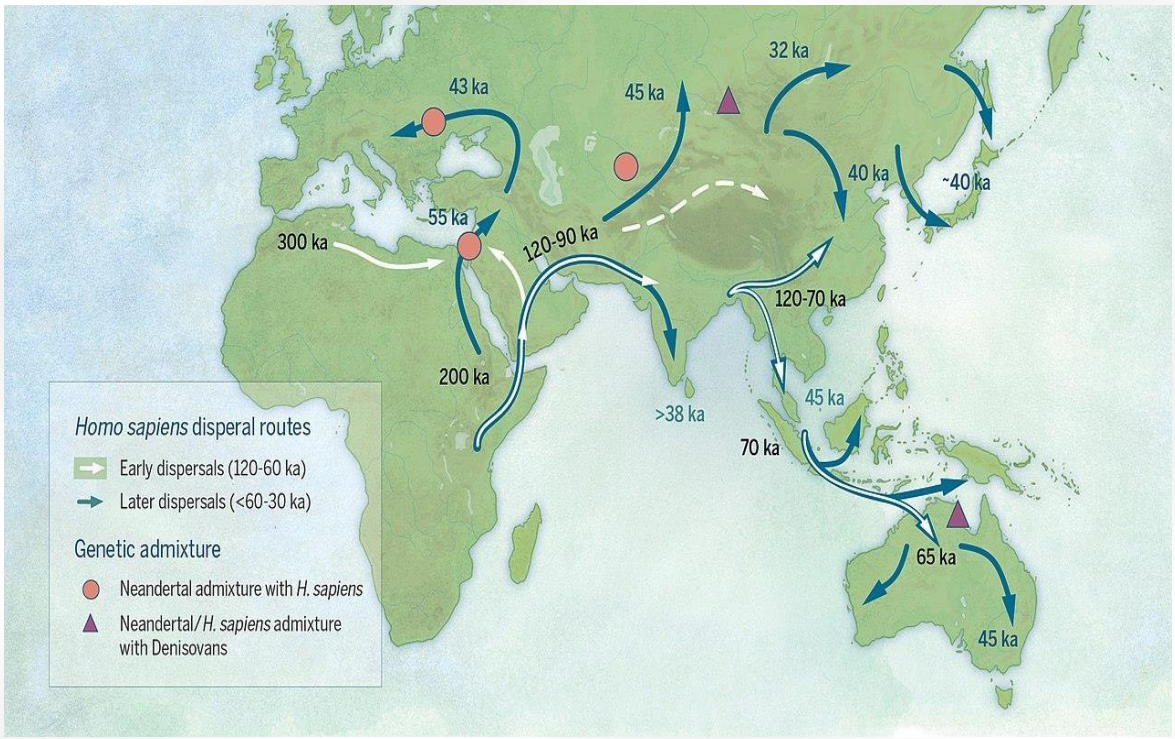


Figure 1.35 The migration of modern humans out of Africa – it all begins near Ethiopia.Numbers indicate the time (in years) since each stage of the migration.

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 that evolved 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 that helps reduce 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 1.13

Dear learner, have you explored the diverse literature and sources discussing the classification of human races and the controversies surrounding it?

Self-evaluation checklist

Put a tick (✓) against each of the following tasks which you can perform

- Can you outline human evolution ☐
- Can you describe the role of paleontological discoveries in Ethiopia in explaining human evolution ☐

🛠 Self-test exercise

Choose the correct answer

1. What distinguished *Homo sapiens f*rom other primates?
   A. A very small brain
   B. Bipedalism
   C. Body size
   D. All
2. Dinknesh (Lucy) belongs to the genus:
   A. *Homo*
   B. *Ardepithecus*
   C. *Australopithecus*
   D. *Pan*
3. The fact that Ardi was bipedal disproves the idea that:
   A. there was a common ancestor of modern humans and chimpanzees
   B. the common ancestor of modern humans and chimpanzees was like a chimpanzee
   C. the common ancestor of modern humans and chimpanzees was intelligent
   D. there was no common ancestor of modern humans and chimpanzees
4. A larger brain gave modern humans an increased ability to:
   A. run faster with a more upright posture
   B. develop and use weapons and tools
   C. plan in advance to avoid attack

D. all of the above

5. Ardi belongs to the genus

A. *Homo*

B. *Ardepithecus*

C. *Australopithecus*

D. *Pan*

Section 1.7 Mutation

Dear learner, in this section, you 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

Dear learner, in the previous section, you have acquired knowledge about significant factors related to human evolution. Now, let us delve into the realm of mutations and explore their various causes in this section.

Could you kindly provide an explanation of mutation and its underlying causes?

Dear learner, a mutation is any spontaneous change in the genetic material of an organism. There can be large structural changes involving the whole chromosomes or parts of chromosomes, or changes that involve only a single base. Changes that involve only a single base are called **point mutations**.

Activity 1.14

Dear leaner, explore and elucidate the causes and effects of mutations on living organisms. By delving into this topic, you can gain a comprehensive understanding of how mutations arise and the diverse impacts they have on living things.

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

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 different protein is made (See Figure 1.36).

Substitution

One amino acid can be substituted by other amino acid. For example, in the following Figure 1.36 methionine replaces isoleucine. 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 1.36). As a result, a different protein will be synthesized, which may or may not be significantly different from the original. One differentamino acid in a protein does not always make a functional change.

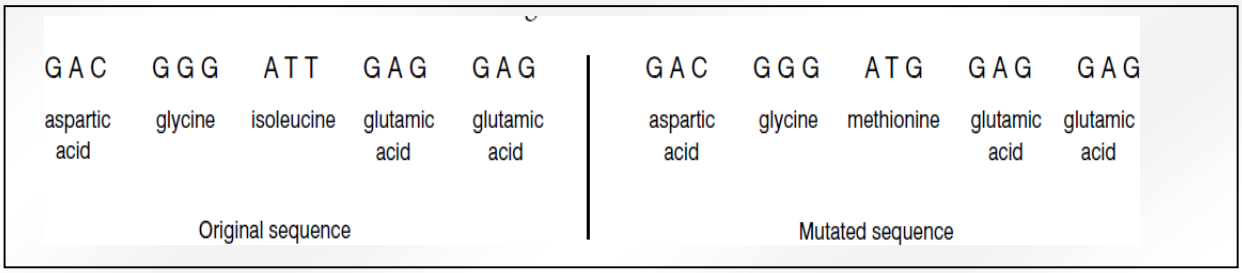


Figure 1.36 A substitution mutation

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**(See Figure 1.37)**.**

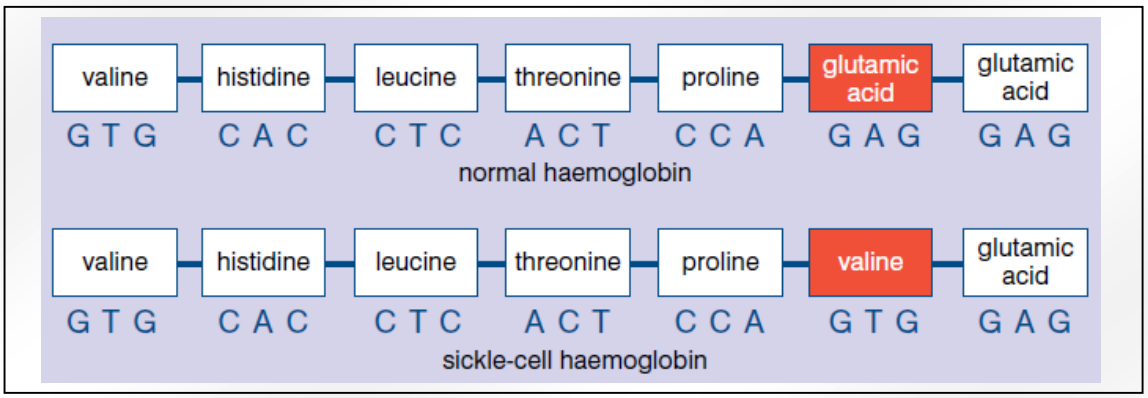


Figure 1.37 Sickle-cell anaemia

Addition and deletion

In a **deletion mutation,** a base is 'missed out' during replication, whereas in additions, an extra base is added (See Figure 1.38). 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 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 oneextra or one fewer codon in themRNA. In turn, this will lead to one extra or one fewer amino acid in the polypeptide chain.

eyword

Deletion mutation *a mutation caused by one DNAnucleotide being omitted from the sequence.*

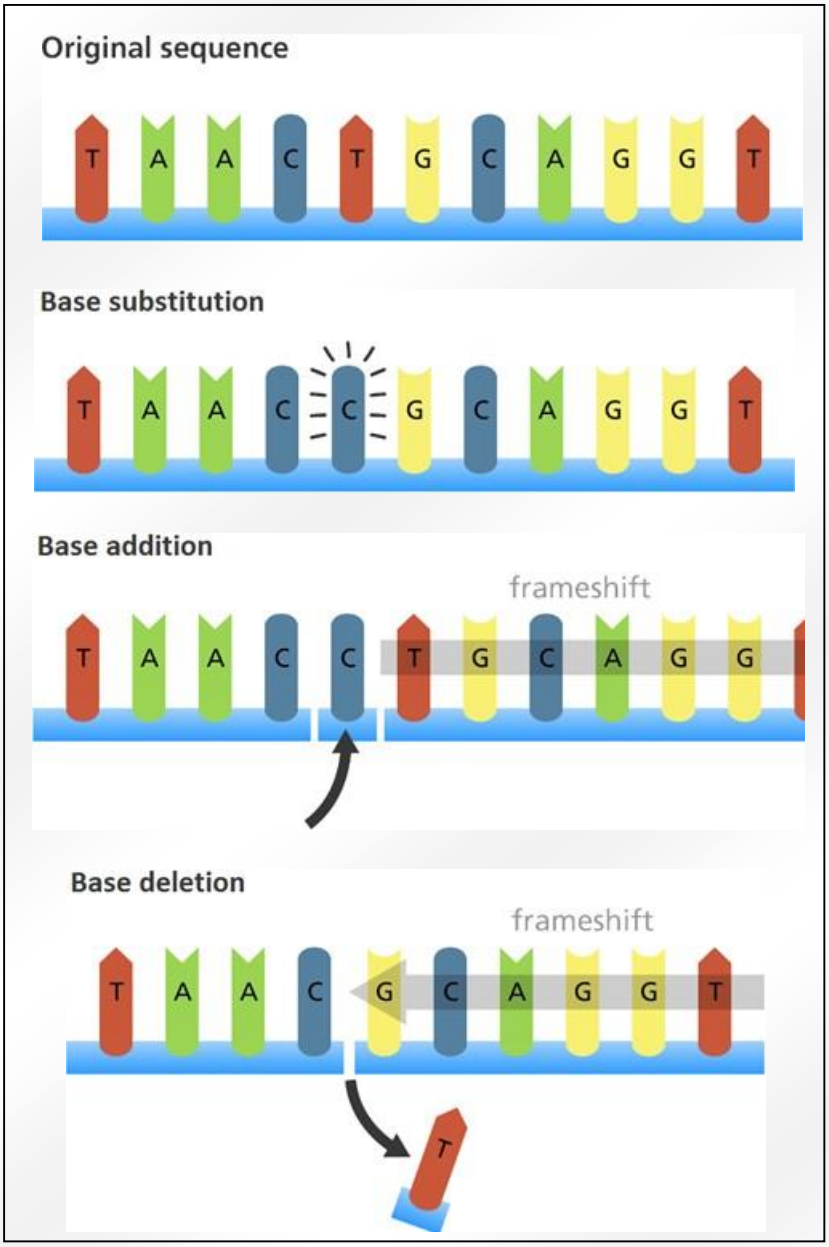


Figure 1.38 Types of point mutation

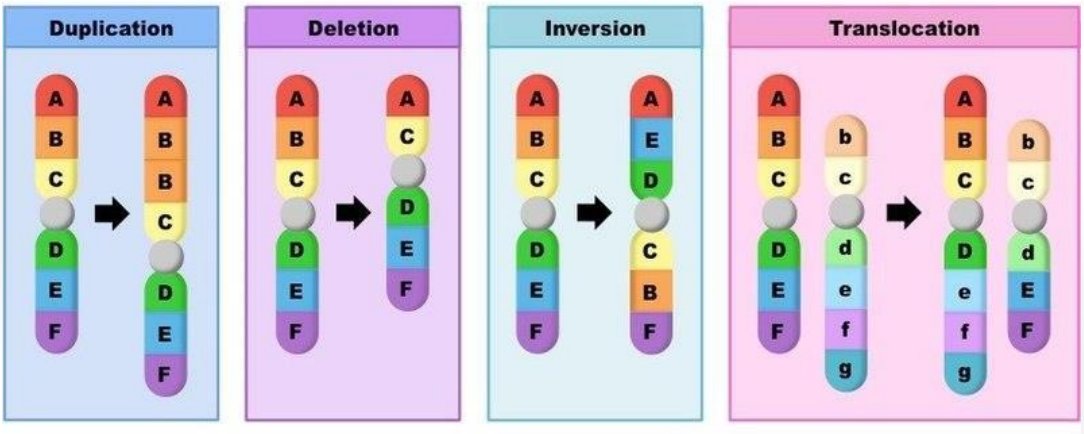
Activity 1.15

Dear learner, can you describe the concept of frameshift mutation using the following example? Consider the sequence of letters: THEMANWASHOTANDRANFORHISHAT. When we organize this sequence into 'reading frames' of three letters each, it reads: THE MAN WAS HOT AND RAN FOR HIS HAT, making sense. However, if we remove the S at the end of WAS (a deletion mutation), it becomes: THE MAN WAH OTA NDR ANF ORH ISH AT.

What causes point mutations and what are the consequences of gene mutations?

Chromosome mutations

Chromosomal mutations occur when there is any change in the arrangement or structure of the chromosomes. They occur most often during meiosis at crossing over in prophase I. Thereare several different mutation types that result in a change in the structure of a chromosome such as duplication, deletion, inversion and translocation (See Figure 1.39). They are much bigger events than point mutations and usually result in the death of a cell. They may also affect thewhole organism. For example, if essential parts of the DNA are affected by chromosomal mutations, a fetus may be aborted.



There are different types of chromosome mutations.

Figure 1.39. Types of Chromosomal mutations

☑ Self-evaluation checklist

Put a tick (✓) against each of the following tasks which you can perform

- Can you define mutation ? ☐
- Can you describe the different types of mutations? ☐
- Can you explain effects of mutation ☐

🛠 Self-test exercise

Choose the correct answer

1. Which of the following is an example of a chromosomal mutation:
   A. a base duplication
   B. a base insertion
   C. a translocation
   D. none of these
2. Which of the following is a frameshift mutation?
   A. point replacement
   B. Inversion
   C. Insertion
   D. substitution
3. Change in the structure of a chromosome can occur as a result of
   A. duplication
   B. deletion
   C. inversion
   D. all
4. Any spontaneous change in the genetic material of an organism
   A. mutation
   B. natural selection
   C. gene flow
   D. none
5. Sickle-cell anaemia is an example of
   A. point mutation B. chromosomal mutation

Section 1.8 Genetic drift

Dear learner, at the end of this section, you will be able to discuss genetic drift.

Dear learner, in the previous section you have learnt about mutation, what causes of mutation and effects of mutations. In this section you will learn about genetic drift.

What is genetic drift?

Dear learner, allele frequencies can change due to chance alone. This is called genetic drift. Drift is a binomial sampling error of the gene pool. In other words, 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 the 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. Avery 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.

Keyword

Genetic drift is a mechanism of evolution in which allele frequencies of a populationchange 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.

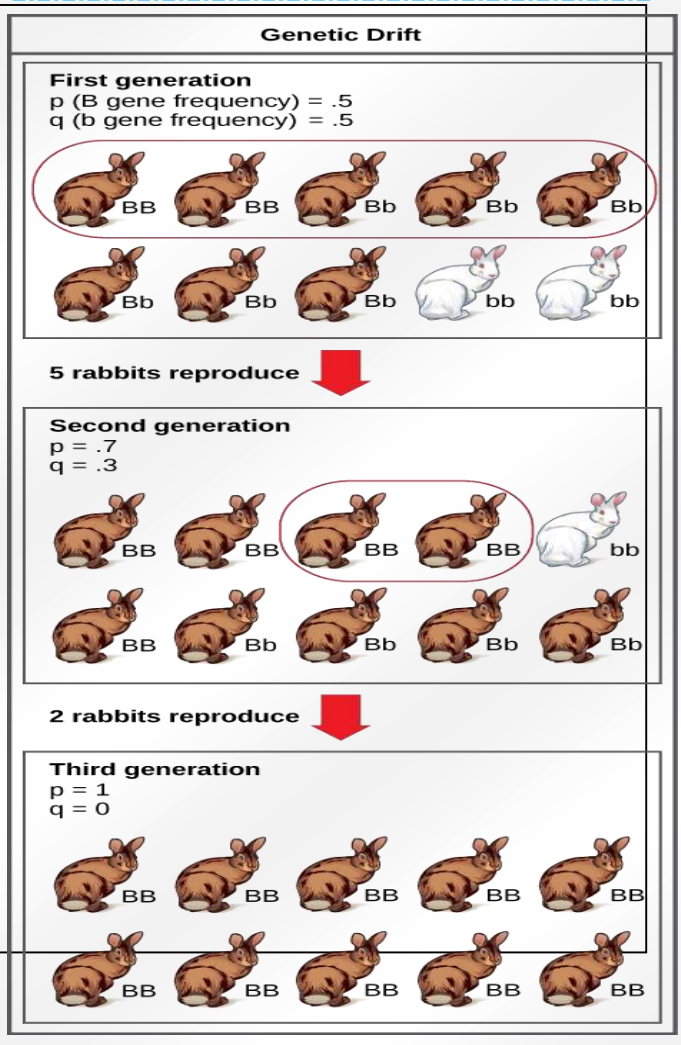


Figure 1.40 Example of genetic drift in a rabbit population

As shown in Figure 1.40, 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? (The other rabbits might have died of other factors not related to the color of their coat. For example, they might have caught 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.

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 shiftedto 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 iscompletely 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.

The bottleneck effect

What is bottleneck effect?

Dear learner, the bottleneck effect is an extreme example of genetic drift that happens when the size of a population is severely reduced. Events such as 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 assortments of individuals survive the event and passthrough 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 (See Figure 1.41) 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 1.16

Dear learner, could you describe how a bottleneck event leads to a reduction in genetic diversity?

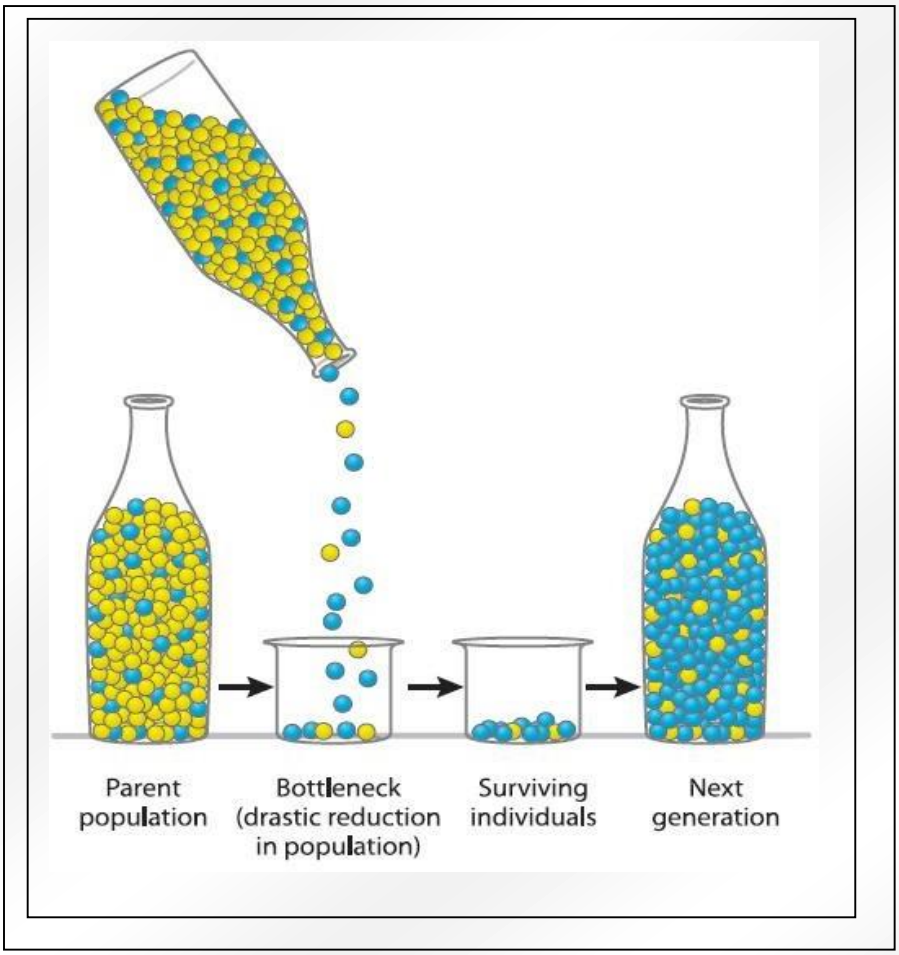


Figure 1.41 Bottleneck effect eliminates genes from a population

The founder effect

What is a 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 (See Figure 1.42).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).

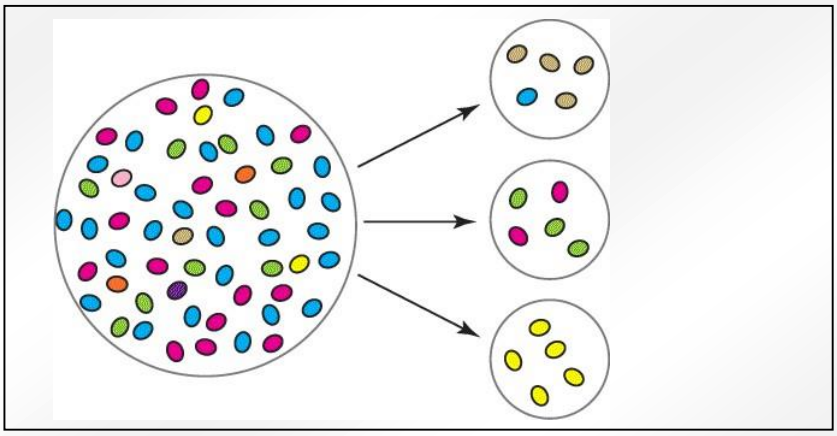


Figure 1.42 Founder effect eliminates genes from a population

Activity 1.17

Dear learner, could you explore and gather information about Ellis-Van Creveld syndrome, which is characterized by symptoms like polydactyly (extra fingers) and other physical abnormalities?.

Gene flow

Dear learner,in this section you will be able to:

- Discuss Gene flow
- Describe the roles of immigration and emigration on gene flow and speciation.

What is gene flow?

Keywords

Gene flow is any movement of individuals, and/or the genetic materialthey carry, from one population to another

Migration: The permanent movementof genes into or out of a population, causing a change in allele frequency

Dear learner, gene flow also called migration- is any movement of individuals, and/or the genetic material carrying 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 1.43 below, the gene version for brown coloration moves from one population to another.

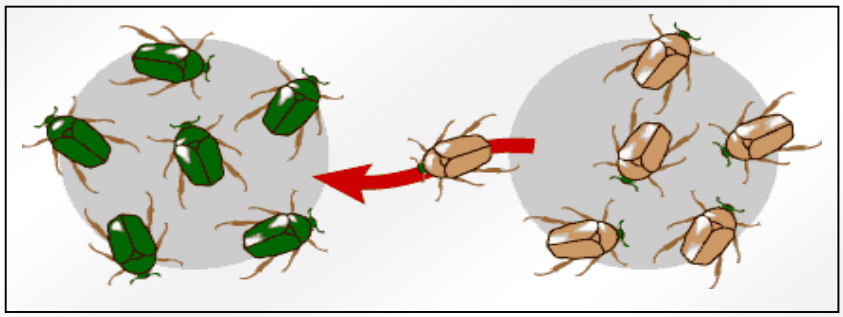


Figure 1.43 Gene flow (immigration)

Immigration occurs when new organisms join a population, changing allele frequencies.

Emigration occurs 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. Gene transfer is especially common in bacteria.

☑ Self-evaluation checklist

Put a tick (✓) against each of the following tasks which you can perform

- Can you define genetic drift? ☐
- Can you describe founder effect? ☐
- Can you explain bottleneck effect ☐
- Can you describe gene flow (immigration) ☐

🛠 Self-test exercise

Choose the correct answer

1. Genetic drift is
   A. a mechanism of evolution in which allele frequencies of a population change over generations due to chance events.
   B. a change due to "sampling error" in selecting alleles from gene pool of the current generation.
   C. Similar with natural selection
   D. A and B
2. In a population where the allele frequency shifts by random chance, the mechanism of evolution at work is
   A. Natural selection
   B. Migration
   C. Genetic drift
   D. Mutation
3. A phenomenon that happens when the size of a population is severely reduced

   A. natural selection

   B. gene flow

   C. genetic drift

   D. foundereffect

4. Any movement of individuals, and/or the genetic material carrying from one population to another

A. natural selection

B. gene flow

C. genetic drift

D. bottleneck effect

5. A phenomenon thatoccurs when a small group of individuals breaks off from a larger population to establish a colony

A. natural selection

B. gene flow

C. genetic drift

D. founder effect

Section 1.9 Causes of species extinction

Dear learner, in this section, you will be able to explain causes of species extinction

Dear learner, in the previous section you have learnt about genetic drift, founder effect, bottleneck effect and gene flow. In this section you are going to learn about causes of species extinction.

❁Dear learner, evidence suggests that anthropogenic effects and natural disaster played significant role forthe direct and indirect causes of species extinction.

Activity 1.18

Dear learner, we encourage you to explore more into the factors driving extinction, including climate change, human activities, greenhouse gases, and natural disasters. Additionally, please explore potential solutions aimed at mitigating habitat loss and preventing further extinctions.

Section 1.10 Renowned anthropologists in Ethiopia

Dear learner, in this section, you will be able appreciate the works of renowned anthropologists in Ethiopia.

Activity 1.19

Dear learner, search the contributions of renowned Ethiopian paleoanthropologist using a variety of sources, including books and the internet.

1.11 Renowned evolutionists in Ethiopia

In this section, you will be able to:

- Appreciate the works of renowned evolutionists in Ethiopia

Activity 1.20

Dear learner, could you search human evolution discoveries made in Ethiopia by exploring various sources, including the internet and other relevant materials? Additionally, please look into the contributions of Ethiopian scientists who have been involved in these discoveries of human evolution in Ethiopia.

Section 1.12 Unit summary

Dear learner, in this unit, you have learnt about evolution which can be defined as the change in genetic composition of a population over successive generations. Moreover, 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 continueto 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 that created 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 forlife could be synthesized on Earth 4.5 billion years ago.
- The oldest photo-autotrophs are the cyanobacteria and they were

largely responsiblefor 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 states 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, detailed account of concepts regarding the origin of life havebeen provided. Based on this, it has been stated that Neo-Darwinism takes into accountour knowledge of genetics, biochemistry and ethology to modify Darwin's original theory to include the effect of selection on allele frequency and frequency of behaviorpatterns.
- 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 todetermine 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 radioactivecarbon 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

summarized below.

- 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 intopopulation whose disadvantageous alleles are lost through natural selection.
- In natural selection:
    - individuals with an advantageous allele survive to reproduce in greaternumbers
    - the process repeats over many generations in which the frequency ofthe 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 theselective 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 aroundthe 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 originalpopulation.
- If two populations of the same species are isolated for sufficient time, they may becomeso different genetically as to evolve into separate species.
- Speciation that involves geographical separation is called allopatric speciation.

- Speciation that involves separation within one area a result of different breedingstrategies is called sympatric speciation;
- 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’sfinches on the Galapagos Islands
- Convergent evolution is the evolution of similar ‘types’ with similar adaptations fromseveral different original ‘types’. Examples include:
    - the elongated ‘snouts’ (and other features) of the different anteaters ofthe world
    - the wings of birds, insects, pterodactyls, etc.
- Modern humans and other primates have evolved from a common primate ancestor thatlived before the dinosaurs became extinct.
- Modern humans and chimpanzees have evolved from a common ancestor that livedabout 6 million years ago.
- Two distinctive features of modern humans are:
    - large brains
    - true bipedalism
- The discovery of Lucy was significant because it showed that bipedalism evolved before largebrains.
- The discovery of Ardi was significant because it showed that the common ancestor of humansand chimpanzees cannot have resembled a chimpanzee.
- Brain size has increased as hominids have evolved.
- Modern humans evolved in Africa, in and near Ethiopia, and have since migrated to allparts of the world.
- Humans evolved into different ‘races’ because natural selection favored differentfeatures in different environments.

Assignment questions

Provide the correct answer for the following questions

1. Discuss one advantage and one disadvantage of the theories on the origin of life mentioned below. In some cases, you may have to imagine yourself as if you were a 'person of the times.
    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) Explain how Neo-Darwinism has modified Darwin's original theory of naturalselection.

3. (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

4. The amino acid sequences of one of the polypeptide chains of haemoglobin from nineanimals 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 hybridization to suggest relationships between species.Explain why

5. Explain the importance of each of the following in speciation:
   - Isolation of different populations
   - Mutation
   - Selection pressures
   - Reproductive isolation
6. Describe how the experiments of Redi and Pasteur were able to disprove the theory ofspontaneous generation.
7. Describe (a) the Oparin/Haldane theory of abiogenesis (the biochemical origin of life).

   (b) Three pieces of evidence that support this theory.
8. Write a short essay on human evolution. Include the following aspects of humanevolution 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 Lucy, Ardi and Selam fossils.
9. How is the age of a rock estimated?
10. Expalin how genetic variation help in evolution?

🔑 Answer Key

Answers for the questions under the various sections are provided below.

Unit one. Evolution

Section 1.2 (Theories of the origin of life)

Correct answers: C-A-A-B-A-B-B-D-C-D

Section 1.3 (Theories of evolution)

Correct answers: D-D-D-D-D-B-B-B-A-C

Section 1.4 (The evidence for evolution)

Correct answers: B-B-C-A-D-B-D-A-D-D

Section 1.5 (Natural selection)

Correct answers: A-B-B-A-B-B-A-A-C-C

Section 1.6 (Human evolution)

Correct answers: B-C-A-D-B

Section 1.7 (Mutation)

Correct answers: C-B-D-A-A

Section 1.8 (Genetic drift, bottleneck effect and gene flow)

Correct answers: D-C-D-D-D

Response to activties

Unit 1

Activity 1.1

1. **Young Earth Creationism**: This theory posits that the Earth and the universe were created by a divine entity within the last 10,000 years, based on a literal interpretation of religious texts such as the Bible's Book of Genesis. Advocates of young Earth creationism typically reject the scientific consensus on the age of the Earth and universe, proposing a young age based on genealogies and biblical chronologies.
2. **Old Earth Creationism**: In contrast to young Earth creationism, proponents of old Earth creationism acknowledge the vast age of the Earth and universe as determined by scientific methods such as radiometric dating. They typically reconcile scientific findings with religious beliefs by asserting that each "day" of creation in the Genesis account represents a long period of time, rather than a literal 24-hour day.
3. **Day-Age and Gap Creationism**: Day-age creationism suggests that each "day" of creation represents a longer geological epoch, aligning with scientific understandings of the Earth's development. Gap creationism posits a time gap between the initial creation event described in Genesis 1:1 and the subsequent "re-creation" described in

Genesis 1:2-31, allowing for an interpretation that accommodates both scientific evidence and religious doctrine.

4. **Progressive Creationism**: This theory proposes that the process of creation occurred incrementally over vast spans of time, with each stage guided or initiated by a divine creator. Progressive creationists often accept the scientific consensus on the age of the Earth and universe, while asserting that specific acts of creation were divinely orchestrated.

5. **Theistic Evolution/Evolutionary Creationism**: Advocates of theistic evolution, also known as evolutionary creationism, believe that the processes of evolution, as described by modern science, were ordained and guided by a divine creator. They reconcile scientific findings on evolution with religious beliefs, viewing the mechanisms of evolution as part of a grander divine plan.

6. Intelligent Design: Intelligent design proponents argue that certain features of the universe and living organisms are best explained by an intelligent cause, rather than naturalistic processes alone. While not strictly a creationist theory in the traditional sense, intelligent design suggests that the complexity and specified information observed in nature point to the involvement of an intelligent designer.

Activity 1.2

The panspermia theory suggests that life could have been transferred from other planets or celestial bodies to Earth through means such as cometary impacts or meteorite collisions.

Activity 1.3

Stanley Miller's experiment simulated the conditions believed to exist on early Earth by creating a mixture of water, methane, ammonia, and hydrogen in a closed system. By passing electric sparks through the mixture to simulate lightning, Miller was able to produce amino acids, which are the building blocks of proteins and essential for life. This experiment provided compelling evidence that the basic building blocks of life could have been formed spontaneously under Earth's early atmospheric conditions, thus contributing significantly to our understanding of the biochemical origins of life.

Activity 1.4

Photoautotrophs are organisms that can produce their own food using sunlight as a source of energy through the process of photosynthesis. They contain chlorophyll or similar pigments that enable them to capture light energy and convert it into chemical

energy. In contrast, chemoautotrophs obtain energy by oxidizing inorganic compounds such as hydrogen sulfide or ammonia. This process does not involve light and relies on chemical reactions to extract energy for the synthesis of organic molecules. Thus, the main difference between photoautotrophs and chemoautotrophs lies in the source of energy they utilize to produce food.

Activity 1.5

Commonly used types of evidence to support Darwin's theory of evolution include fossil records, comparative anatomy, embryology, biogeography, and molecular biology. Fossil records provide physical evidence of species that have evolved over time. Comparative anatomy shows similarities in the structure of different species, indicating a common ancestry. Embryology demonstrates similarities in the development of different species during embryonic stages. Biogeography examines the distribution of species across different regions. Molecular biology studies genetic similarities and differences among species to trace evolutionary relationships. Collectively, these types of evidence provide strong support for Darwin's theory of evolution.

Activity 1.6

Homologous structures exist in organisms that have a common ancestor whereas analogous structures are found in organisms that do not have a common ancestor. Analogous structures always have similar or identical functions, while homologous structures are not always the case.

Activity 1.7

During embryogenesis, certain developmental stages or features in an embryo may resemble ancestral forms or structures found in its evolutionary lineage. This process is often referred to as embryonic recapitulation. For example, early vertebrate embryos exhibit gill-like structures reminiscent of ancestral aquatic organisms, even though these structures may not persist in the adult form.

Activity 1.8

Fossil formation typically occurs when organisms or their remains are buried in sediment, which protects them from decay. Over time, as more sediment accumulates, pressure and mineralization turn the organic material into rock-like fossils. This process, called fossilization, preserves the structure of the organism and provides valuable insights into past life forms and environments.

Activity 1.9

Scientists determine the age of rocks using various methods such as radiometric dating, which relies on the decay of radioactive isotopes in minerals. By measuring the ratio of parent to daughter isotopes, they can calculate the age of the rock. This helps to determine the age of each geological layer. The concept of half-life time refers to the time it takes for half of the radioactive isotopes in a sample to decay. This plays a crucial role in radiometric dating, allowing scientists to accurately determine the age of rocks and geological formations.

Activity 1.10

Allopatric speciation occurs when a population is geographically isolated, leading to reproductive barriers and eventual divergence into separate species. In contrast, sympatric speciation occurs within the same geographic area, often due to ecological or behavioral factors, resulting in the emergence of distinct species from a common ancestor without geographical isolation.

Activity 1.11

The complex narrative of human evolution spans millions of years, showcasing the gradual development and adaptation of our ancestors from ancient primates to modern *Homo sapiens*. It involves a complex interplay of biological, environmental, and behavioral factors, evidenced by fossil records, genetic studies, and archaeological findings. This journey highlights the evolution of bipedalism, brain expansion, tool use, social behavior, and cultural advancements, reflecting our species' remarkable ability to adapt and thrive in diverse environments over time.

Activity 1.12

Ethiopia stands as a cornerstone in the narrative of human evolution due to its rich fossil record and pivotal discoveries. Lucy, a 3.2 million-year-old *Australopithecus afarensis* fossil found in the Afar region in 1974, revolutionized our understanding of human origins. This remarkably complete skeleton provided insights into bipedalism, a crucial adaptation in human evolution. Similarly, the discovery of *Ardipithecus ramidus*, (Ardi), in the Middle Awash region in 1994 challenged previous assumptions. Ardi, dating back over 4 million years, offered insights into the early stages of hominin evolution, shedding light on traits such as bipedalism and forest adaptation. Additionally, the discovery of Selam, an *Australopithecus afarensis* child fossil, in the Dikika region in 2000 provided unprecedented insights into the growth and development of early hominins. This fossil offered clues about *Australopithecus*

afarensis' social structure and behavior. These discoveries underscore Ethiopia's significance as a cradle of humanity and highlight the country's critical role in advancing our understanding of human evolution.

Activity 1.13

The classification of human races involves categorizing populations based on observable physical traits. However, controversies arise due to the arbitrary nature of race boundaries, inconsistencies in definitions, and the lack of biological basis for race. Critics argue that racial classifications perpetuate stereotypes, prejudice, and discrimination, and fail to capture the complexity of human diversity. Additionally, race has been misused historically to justify oppression. Addressing these controversies requires acknowledging the fluidity of human traits and the social constructs that shape perceptions of race.

Activity 1.14

Mutations, which are alterations in an organism's DNA sequence, can arise from various sources such as environmental factors like radiation, chemicals, or errors during DNA replication. These mutations can have both positive and negative effects on living organisms. Positive effects include providing genetic variation essential for evolution, enabling adaptation to changing environments, and sometimes leading to beneficial traits like antibiotic resistance in bacteria. However, mutations can also result in negative consequences such as genetic disorders, developmental abnormalities, or increased susceptibility to diseases. These effects can manifest at the individual level or have broader implications for populations. Understanding the causes and effects of mutations is crucial in fields like medicine, agriculture, and conservation biology, as it helps us comprehend genetic diversity, disease mechanisms, and the potential impacts of environmental stressors on living organisms.

Activity 1.15

Frameshift mutation occurs when nucleotides are inserted or deleted from the DNA sequence, altering the reading frame during translation. In the provided example, removing the letter "S" from "WAS" shifts the reading frame, resulting in a completely different sequence: "THE MAN WAH OTA NDR ANF ORH ISH AT." This mutation can lead to significant changes in the amino acid sequence of the resulting protein, often resulting in non-functional or dysfunctional proteins.

Activity 1.16

A bottleneck event occurs when a population undergoes a drastic reduction in size, leading to a significant loss of genetic diversity. This reduction happens because only a small portion of the original population survives to repopulate, resulting in a limited gene pool. As a result, genetic variation is greatly reduced, which can make the population more susceptible to genetic disorders, diseases, and environmental changes.

Activity 1.17

Ellis-Van Creveld syndrome is a rare genetic disorder characterized by various physical abnormalities, including polydactyly (extra fingers), short stature, and congenital heart defects. Other common features may include abnormalities of the teeth, nails, and bones. This syndrome is caused by mutations in the EVC or EVC2 genes, which play a role in skeletal development.

Activity 1.18

The factors driving extinction, such as climate change, human activities, greenhouse gases, and natural disasters, contribute to habitat destruction and loss of biodiversity. Climate change alters ecosystems, affecting species' habitats and survival. Human activities like deforestation, pollution, and overexploitation of resources further degrade habitats and threaten species. Greenhouse gases exacerbate climate change, leading to more extreme weather events that can disrupt ecosystems. Natural disasters like wildfires and hurricanes also pose immediate threats to species survival.

To mitigate habitat loss and prevent further extinctions, solutions include conservation efforts such as habitat restoration, protected area establishment, and species reintroduction programs. Sustainable land management practices, reducing carbon emissions, and promoting renewable energy sources can help combat climate change. Additionally, raising awareness, implementing stricter regulations on wildlife trade, and fostering community involvement in conservation efforts are essential steps in preserving biodiversity and preventing extinction.

Activity 1.19

Some renowned Ethiopian paleoanthropologists and their work:

1. Dr. Berhane Asfaw:

Dr. Berhane Asfaw is a prominent Ethiopian paleoanthropologist known for his significant contributions to the study of human evolution. He has been involved in numerous fossil discoveries in Ethiopia's Rift Valley, including the identification of early hominin species such as *Ardipithecus kadabba* and *Australopithecus garhi*. Dr.

Asfaw's work has greatly advanced our understanding of the origins and evolutionary history of Homo sapiens.

2. Dr. Zeresenay Alemseged:

Dr. Zeresenay Alemseged is an esteemed Ethiopian paleoanthropologist renowned for his groundbreaking discoveries of early hominin fossils. He is best known for his discovery of the fossilized remains of "Selam," a 3.3 million-year-old Australopithecus afarensis child, which provided valuable insights into the locomotion and development of early hominins. Dr. Alemseged's work has significantly expanded our knowledge of human evolution and garnered international acclaim.

3. Dr. Yohannes Haile-Selassie:

Dr. Yohannes Haile-Selassie is a distinguished Ethiopian paleoanthropologist recognized for his contributions to the study of early hominins. He has led numerous fossil discoveries in Ethiopia, including the identification of *Australopithecus anamensis* and the oldest known representative of the genus Homo, dating back over 2.8 million years. Dr. Haile-Selassie's research has provided critical insights into the evolutionary relationships and adaptations of our early ancestors.

Activity 1.20

Here are some Ethiopian scientists who have been involved in the discoveries of human evolution in Ethiopia:

1. Dr. Zeresenay Alemseged: Renowned for discovering the fossilized remains of "Selam," an early hominin Australopithecus afarensis child, Dr. Alemseged has been instrumental in advancing our understanding of human evolution.

2. Dr. Yohannes Haile-Selassie: A leading paleoanthropologist, Dr. Haile-Selassie has made significant contributions to the study of human evolution, including the discovery of Australopithecus anamensis and the earliest known Homo fossil.

3. Dr. Berhane Asfaw: A prominent Ethiopian paleoanthropologist known for his involvement in numerous fossil discoveries in Ethiopia's Rift Valley, including Ardipithecus kadabba and Australopithecus garhi.

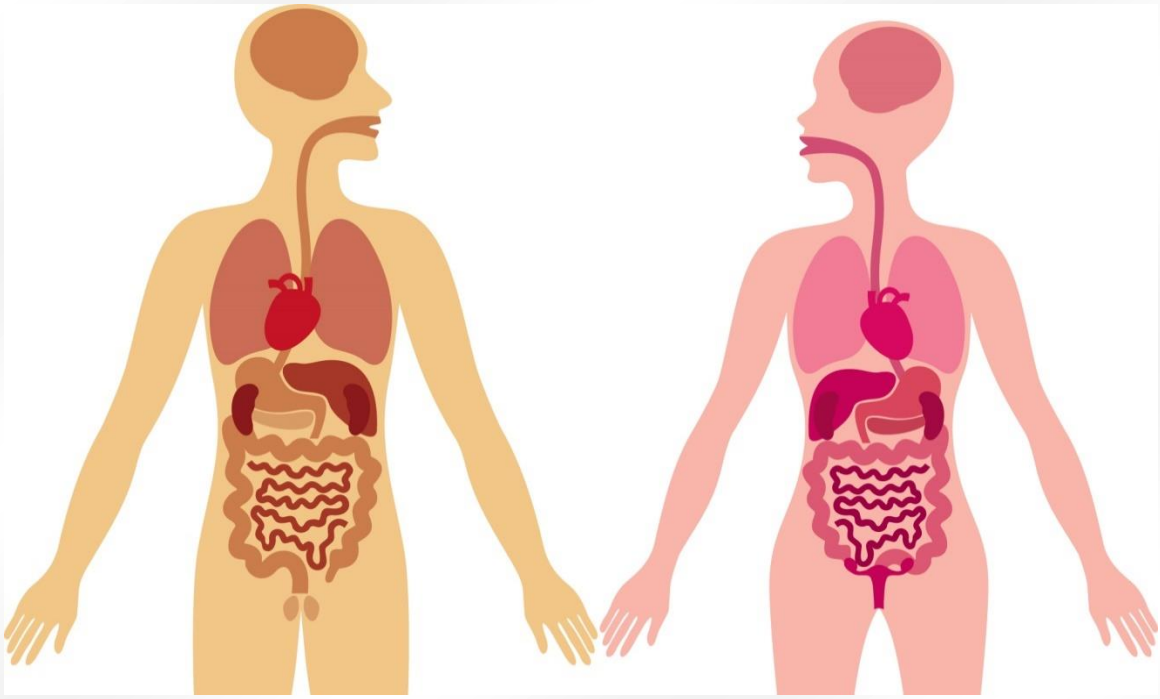
4. Dr. Giday WoldeGabriel: A geologist who has contributed to the dating and stratigraphic analysis of fossil-bearing deposits in Ethiopia, helping to contextualize human evolution discoveries within their geological framework.

5. Dr. Sileshi Semaw: An Ethiopian archaeologist and paleoanthropologist known for his work at the Gona Project in Ethiopia, where he has excavated numerous early stone tools and hominin fossils.

Ethiopian scientists have played crucial roles in the discoveries of human evolution in their country's Rift Valley. Some notable contributions include:

1. Leading expeditions: Ethiopian scientists have led and participated in numerous expeditions to key fossil sites in the Rift Valley, facilitating the discovery of important hominin fossils.
2. Fossil discoveries: Ethiopian scientists have discovered and excavated significant hominin fossils, such as Australopithecus afarensis ("Lucy") and *Ardipithecus kadabba*, providing critical insights into human evolution.
3. Research and analysis: Ethiopian scientists have been actively involved in researching and analyzing hominin fossils found in Ethiopia, contributing to our understanding of the evolutionary history of early humans.
4. Advocacy and education: Ethiopian scientists have advocated for the preservation of fossil sites and promoted public awareness and education about human evolution, both locally and internationally.

UNIT TWO: THE HUMAN BODY SYSTEM



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Unit overview

Dear learner, welcome to the second unit of the second module. In this unit you will learn about The Human Body System particularly about Human Nervous System. You will obtain detail information about the structure of nervous system, functions of different types of neurons, reflex action, the mechanism of the conduction of nerve impulse and the different types of drugs and their effect on the nervous system. is also discussed in this unit. You will also learn about the different types of sense organs such as the skin, tongue, nose and eye and their function. Moreover, you will also learn about endocrine glands, the different types of hormones and their function in human body coordination.

Unit study time (31 hrs)

Dear leraner, the required time to accomplis unit two is 31 hrs. You should use the allocated time properly to cover the contents of unit two.

Unit learning outcomes

Dear learner, after successful completion of this unit, you 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 impulse.
- 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
- Define endocrine 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

Body Coordination

How would you define body coordination and what are the various forms of coordination found in the human body?

Dear learner, it is important to understand the two main forms of coordination in animals: nervous and hormonal coordination (see Table 2.1) . The nervous system utilizes nerve cells to transmit electrical impulses, which stimulate target cells by releasing neurotransmitters directly onto them. On the other hand, the endocrine system produces hormones that are transported through the blood plasma to target cells. These target cells have specific receptors on their cell-surface membranes, and changes in hormone concentration stimulate them

Activity 2.1

Dear learner, can you identify which parts of the body systems are involved in coordinating rapid responses to environmental changes?

Table 2.1. 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

Section 2.1 The Nervous System

Dear learner, after successful completion of this section, you 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

Activity 2.2

Dear learner, upon reviewing the following section, could you please provide an explanation of the constituents of both the central nervous system and the peripheral nervous system?

The nervous system

What is the nervous system?

How many major divisions are there in the nervous system?

Dear learner, it is importat to understand nervous system and its role in processing sensory information. The nervous system has two main divisions, illustrated in Figure 2.1. Firstly, we have the central nervous system (CNS), which includes the brain and spinal cord. Secondly, we have the peripheral nervous system (PNS), which consists of nerves located outside of the CNS. These two divisions work together to ensure that your body can receive and interpret sensory information from both its internal and external environments.

What are the precise functions performed by the nervous system??

❁ 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 through the PNS to the CNS.

2. The CNS performs information processing and integration, sums up the input it receives from all over the body.

3. The CNS generates motor output. Nerve signals from the CNS go through the PNS to the muscles, glands, and organs.

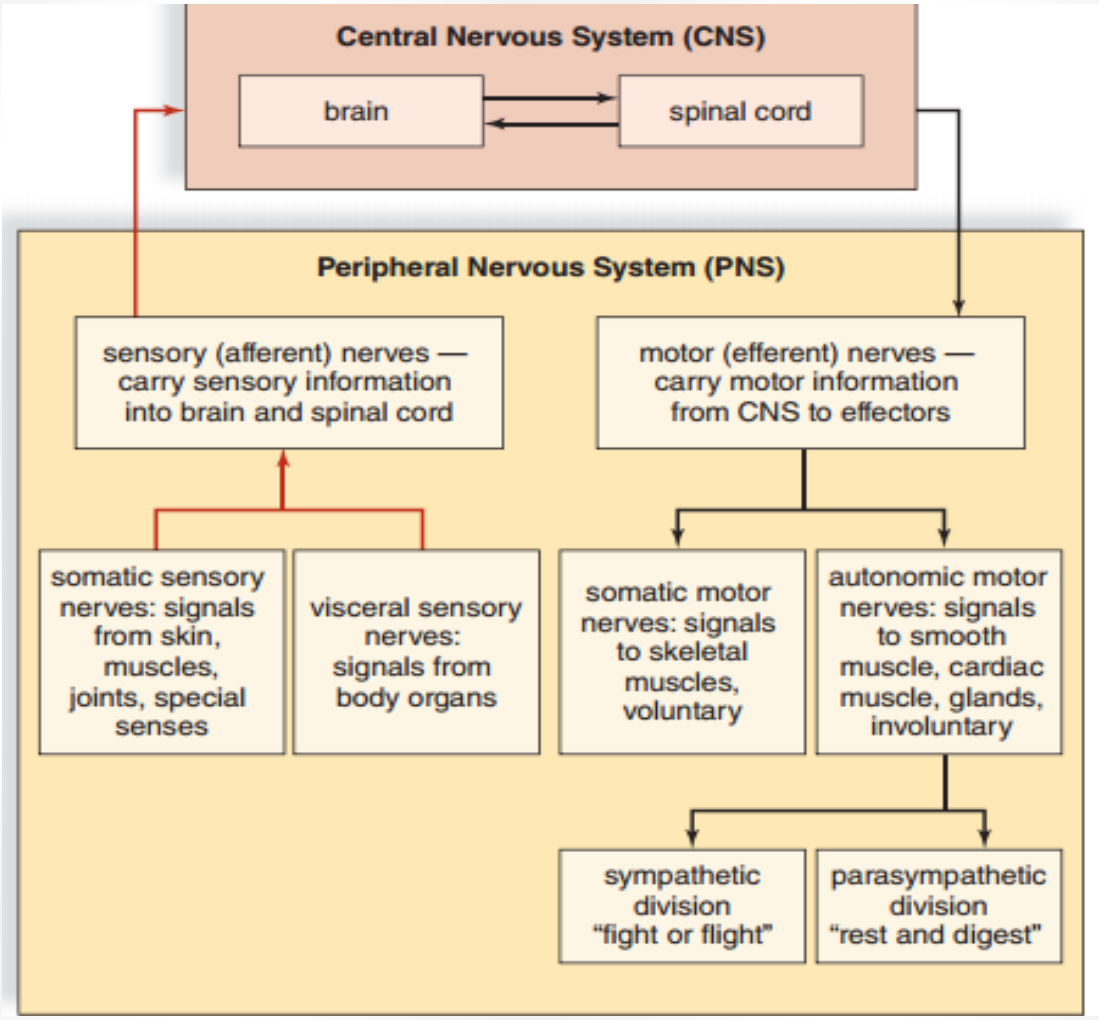


Figure 2.1 The Nervous system with their brief functions

2.1.1 Neurons and their functions

Dear learner, at the end of this section you will be able to:

- Describe the structure of neurons.
- Mention the three types of neurons.
- Describe the function of neurons.

Activity 2.3

Dear learner, can you describe the functional differences between neurons and glial cells?

Dear learner, the nervous system comprises 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 in responding to physical and chemical stimuli, conducting electrochemical impulses, and releasing 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.

What is a neuron?

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 (See Figure 2.2). 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. The cell body also known as a soma 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 neuron has only one axon that carries information away from the cell body. The axon will also branch at its terminal into many **axon terminals**. Axon terminals are distal terminations of the telodentria or branches of an axon. The axon delivers the impulse to another neurone or a gland or a muscle. Individual axons are termed nerve fibers, which collectively 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. Dendrites conduct electrical impulses toward the cell body of the nerve cell. Dendrites collect and store all incoming impulses from axon terminals. 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 generally depends on their role.

Myelin sheath: Myelin is a fatty substance whose purpose is to protect the neurone by electrically insulating it and speeding up its impulse transmission. The axons of the peripheral nerves are long or large axons 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.

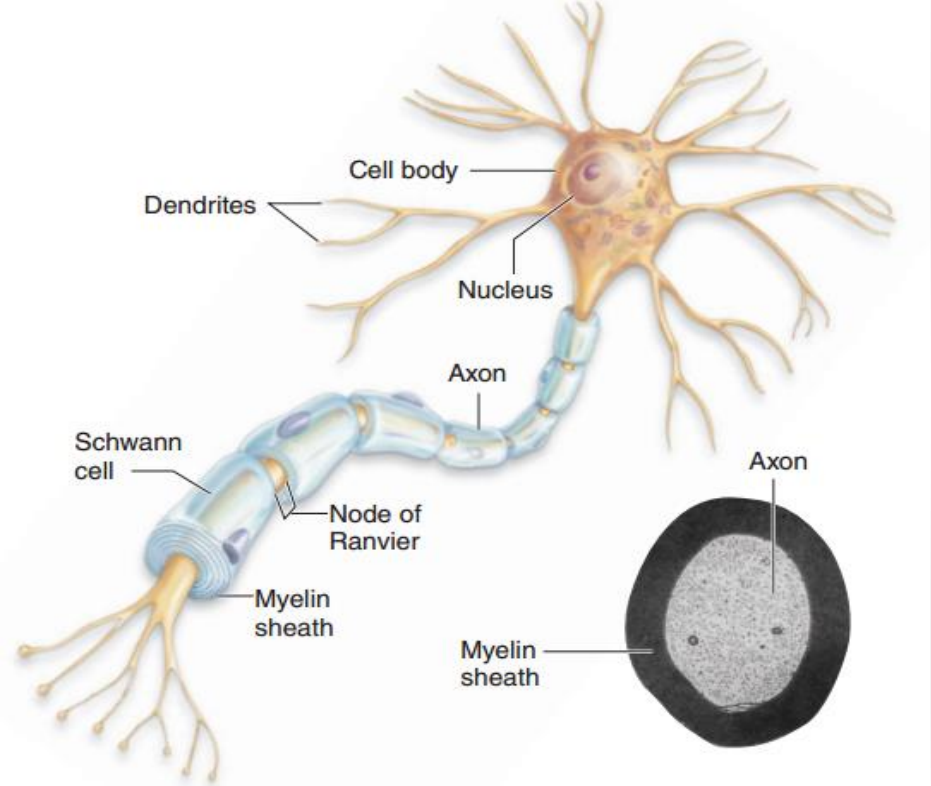


Figure 2.2 Parts of a neuron

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

Types of neurons

Activity 2.4

Dear learner,

1. Could you explain the distinction between a neuron and a nerve?
2. In your opinion, do you believe neurons are continuous structures alike to a 'wire'?

What are the three types of neuron? How do they vary in function?

Dear learner, 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.

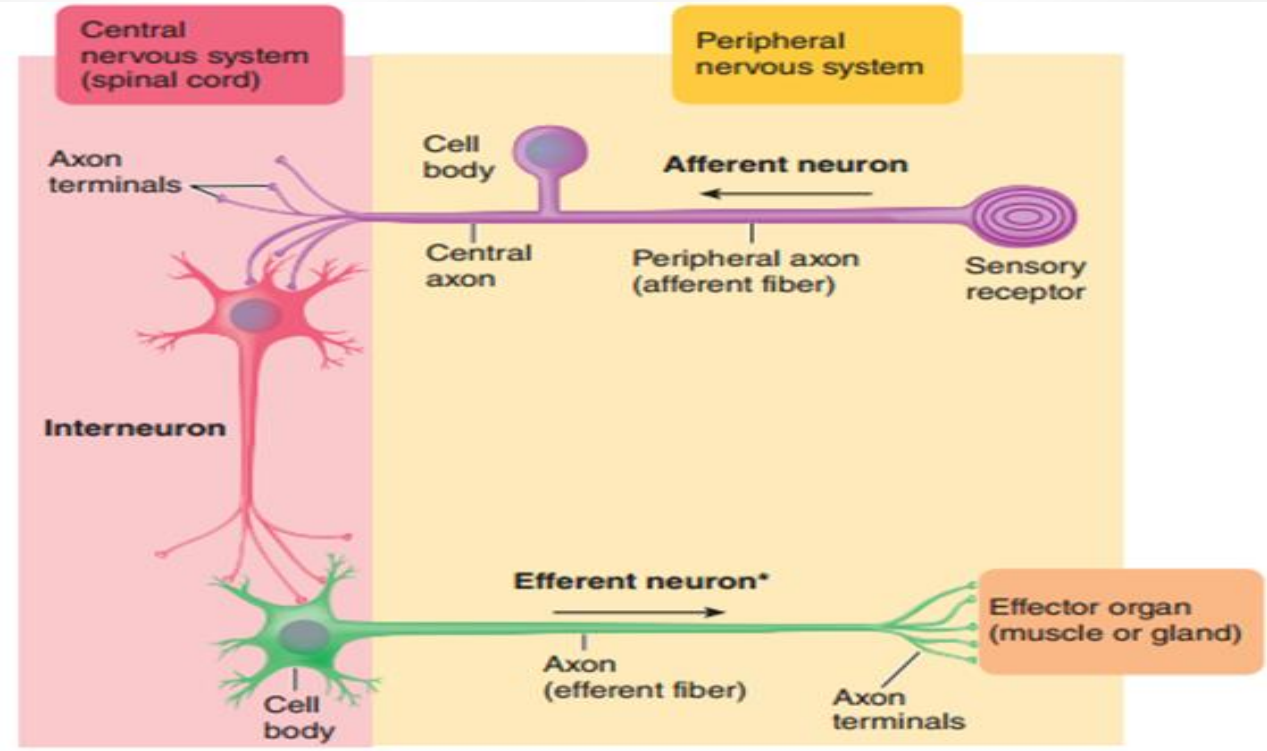


Figure 2.3 Types of neurones

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 flow through the nervous system can be presented 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

What is a nerve?

A **nerve** is a group of neurons (bundles of neurons) with blood vessels and connective tissue. The following are types of nerves.

Sensory (afferent) nerves are made only of sensory neurons. The optic nerves for vision and olfactory nerves for smell are examples of nerves that have 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. While these tracts are often referred to as **white matter**; the myelin sheaths of the neurons give them a white color.

2.1.2 The Nerve Impulse and transmission

Activity 2.5

Dear learner,

1. Can you explain the significance of synapses in neurotransmission?
2. What is an action potential?
3. How does an action potential propagate from one neuron to another?
4. How does an impulse pass from one neuron to another?

Dear learner, at the end of this section, youwill be able to;

- Explain nerve impulse and transmission.

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.

How do you explain action potential?

Dear learner, the nervous system relies on nerve impulses that travel 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 in which 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 (See Figure 2.4). This is called the **resting potential** because the axon is not conducting an impulse.

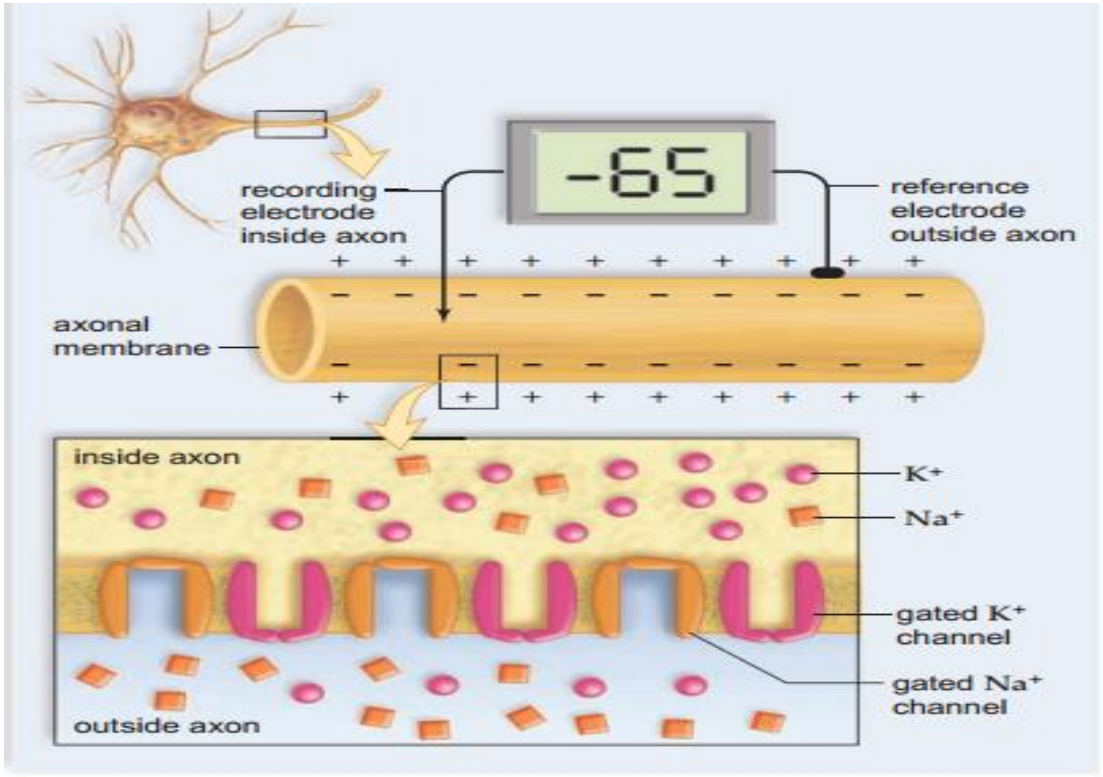


Figure 2.4 Resting potential

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 the 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.
- 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.
- 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 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

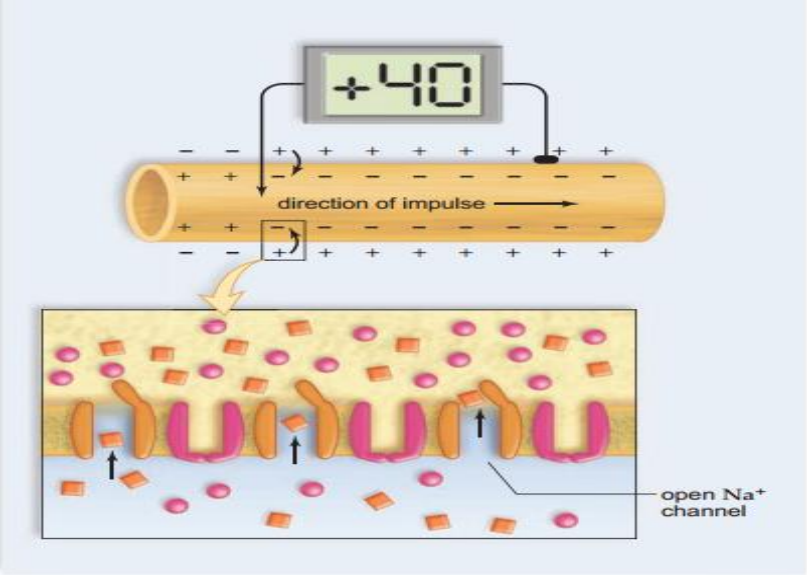


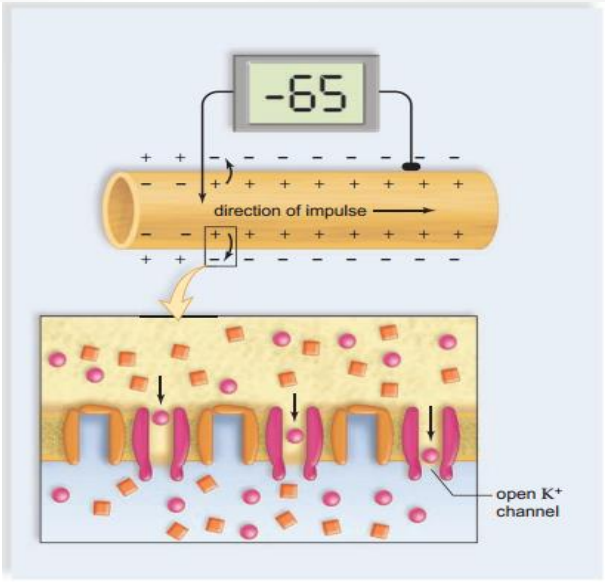
Figure 2.5 Action potential begins: depolarization occurs

Repolarization

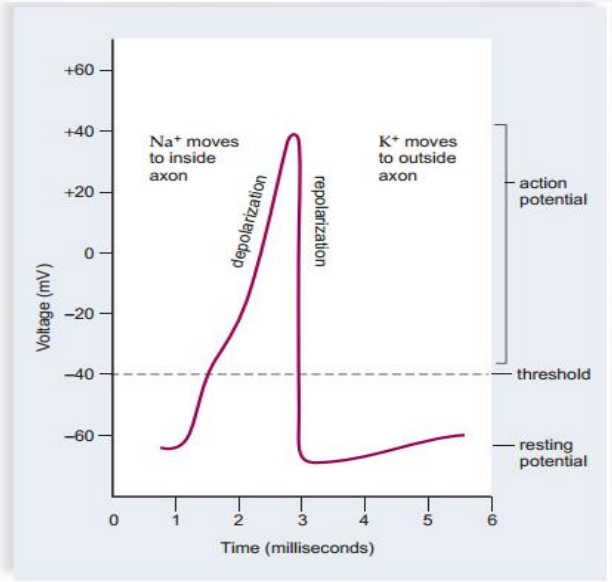
- When sodium channels are closed potassium and channel are opened, K^+ions diffuse out along their concentration gradient. This starts repolarization and resting potential going to reestablish.
- At the same time nerve become less permeable for Na^+than K^+. So many K^+ flow out and inside charge become 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: 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 that allows Na ions to pass through the membrane, and the other that allows 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

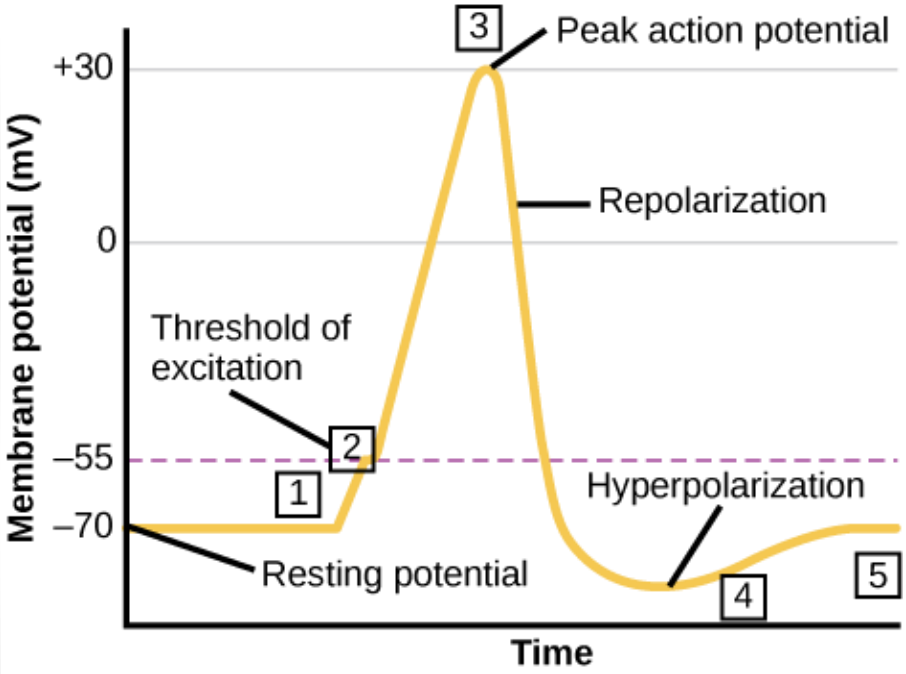


Figure 2.6 Conduction of Action Potentials

Syanapse

Dear learner, at the end of this section you will be able to;

- Explain how impulse crosses the synaptic cleft
- Describe the function of acetylecholinestrase

Activity 2.6

Dear learner, could you provide an explanation of how synapses function?

What is a synapse?

Whenever one neuron ends and another begins, there is a gap known as a s **synapse**.

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, whereas the axon terminals, which hold the **synaptic vesicles** 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 because its 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 (See Figure 2.7). 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, whereas dendrites do not have. 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.

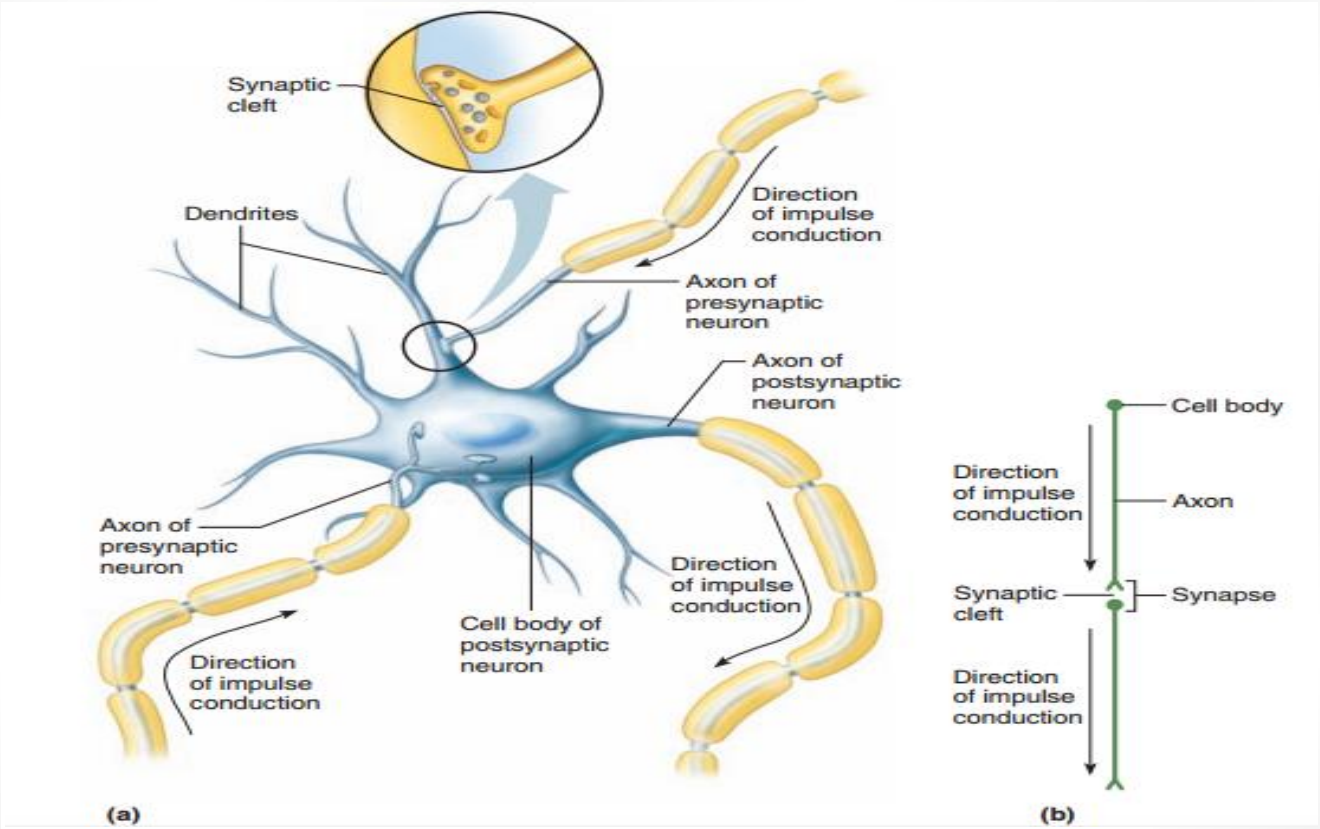


Figure 2.7 Synapsis occurs from axon terminal one neuron to the denderities or cell body another neuron

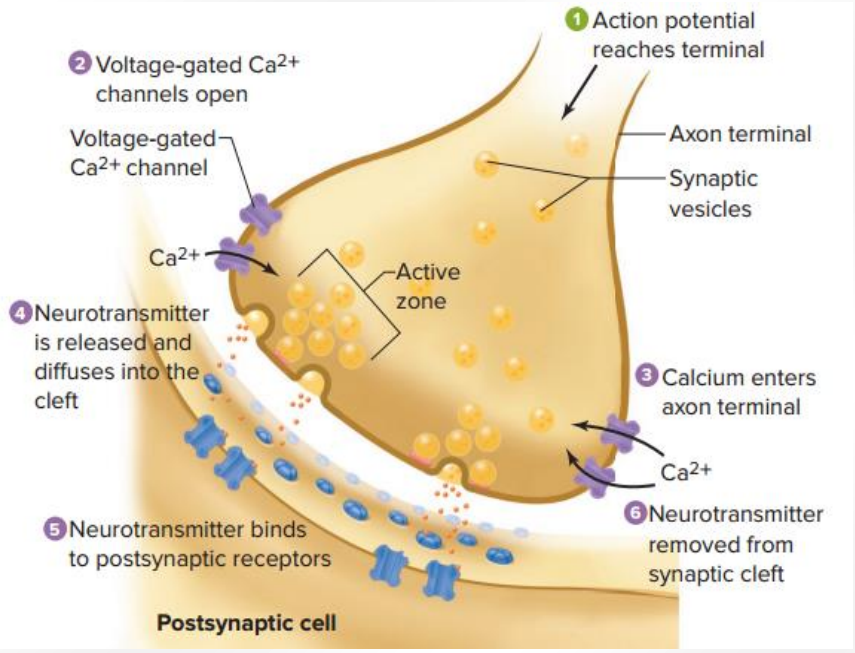


Figure 2.8 Signal transmission through a synapse.

2.1.3 Neurotransmitters

Dear learner, at the end of this section you will be able to:

- Describe the role of neurotransmitters.

What are 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. The excitatory or inhibitory state of a neurotransmitter depends on the receptor it binds to.

Activity 2.7

Dear learner, could you explore more regarding neuromuscular junctions, specialized types of synapses, the different kinds of neurotransmitters, and their respective roles in the nervous system?

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).

☑ Self-evaluation checklist

Put a tick (✓) against each of the following tasks which you can perform

- Can you describe the structure and function of a neuron ☐
- Can you explain nerve impulse and transmission ☐
- Can you explain types of neurons ☐
- Can you describe neurotransmitters and their function ☐
- Can you explain synapse ☐

🛠 Self-test exercise

Choose the correct answer

1. One of the following is NOT specific functions of the nervous system

A. The nervous system receives sensory input.

B. The central nervous system (CNS) performs information processing and integration, sums up the input it receives from all over the body.

C. The CNS generates motor output. D. None

2. Identify the CORRECT statement

A Sensory (affector/ afferent) neurons carry messages from sensory receptors to the central nervous system.

B Motor (effector/ efferent) neurons transmit messages from the central nervous system to the effectors (muscles or glands).

C. Interneurons (association neurons) pass signals from sensory to motor neurons, or to integrate these functions.

D. All

3. Which of the following are the parts of neurons?

A. Axon, dendrite and cell body

B. Synapse and myelinsheeth

C. Nerve and nerve tract

D. None

4. One of the following is NOT true about dendrites.

A. Dendrites are short extensions that receive signals from sensory receptors

B. Dendrites conduct electrical impulses toward the cell body of the neuron.

C. Dendrites conduct electrical impulses away from the cell body of the neuron

D. Dendrites collect and store all incoming impulses from axon terminals

5. Neurons are

A. The basic structural and functional units of the nervous system.

B. They are specialized to respond to physical and chemical stimuli,

C. They conduct electrochemical impulses, and release chemical regulators.

D. All

6. Axon

A. Carries information away from the cell body.

B. Carries information towards the cell body.

B. Delivers impulse to another neuron or a gland or a muscle

D. All

7. A group of neurons with blood vessels and connective tissue is

A. Dendrite

B. Nerve

C. Myelen sheeth

D. Axon terminal

8.Synapse

A. Is a structure that permits a neuron to pass an electrical signal to another neuron or to the effector

B. Is a gap between two neurons

C. Is a structure located on the surface of a neuron

D. A and B

9. Neurotransmitters

A. Referred to as the body's chemical messengers.

B. Are molecules used by the nervous system to transmit messages between neurons, or from neurons to muscles

C. Are released from synaptic vesicles

D. All

10. The wave of positive charge inside the axon when the neuron is stimulated is known as

A. Action potential

B. Resting potential

C. Polarization

D. Repolirization

2.1.4 Types of the nervous system

Dear learner, at the end of this section, you will be able to:

- Identify types of the nervous system

How do you differentiate the central nervous system and peripheral nervous system?

Dear learner, 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 that sends this information back to the brain

A. The Central Nervous System

The Central Nervous System (CNS) consists of two main parts: the **brain** and the **spinal cord**.

Activity 2.8

Dear learner, can you explain which parts your body systems get involved for coordination and rapid responses to the changes in the environment?

The Brain

The tissue of the central nervous is delicate. Because of this characteristic, and nerve cells cannot be replaced when they are damaged. Therefore, this fragile, irreplaceable tissue must be well protected. The following four major features help protect the CNS from injury:

1. It is enclosed with 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 the CSF.

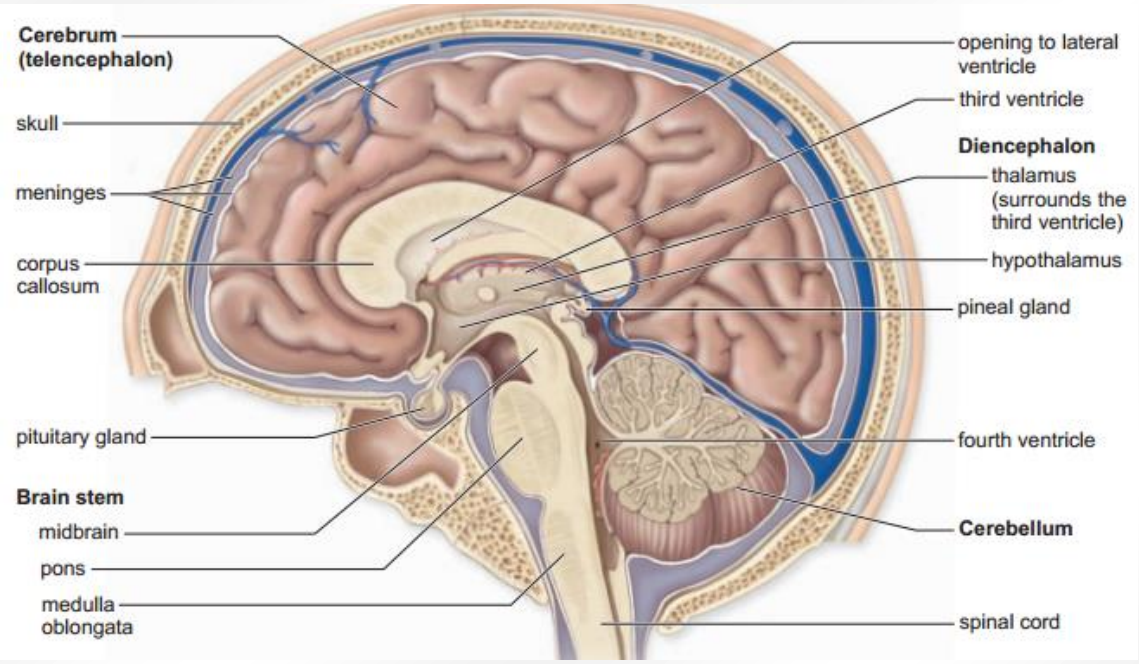


Figure 2.9 Parts of humann brain

Protected within the skull, the brain is composed of the **cerebrum**, **cerebellum**, and **brainstem (Medula)** (See Figure 2.9).

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 such as 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 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 through 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 people for learning of new motor skills. 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 as its name indicates, the pons contains bundles of axons traveling between the cerebellum and 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 responsible 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.

Medulla (Brainstem)

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 commands.

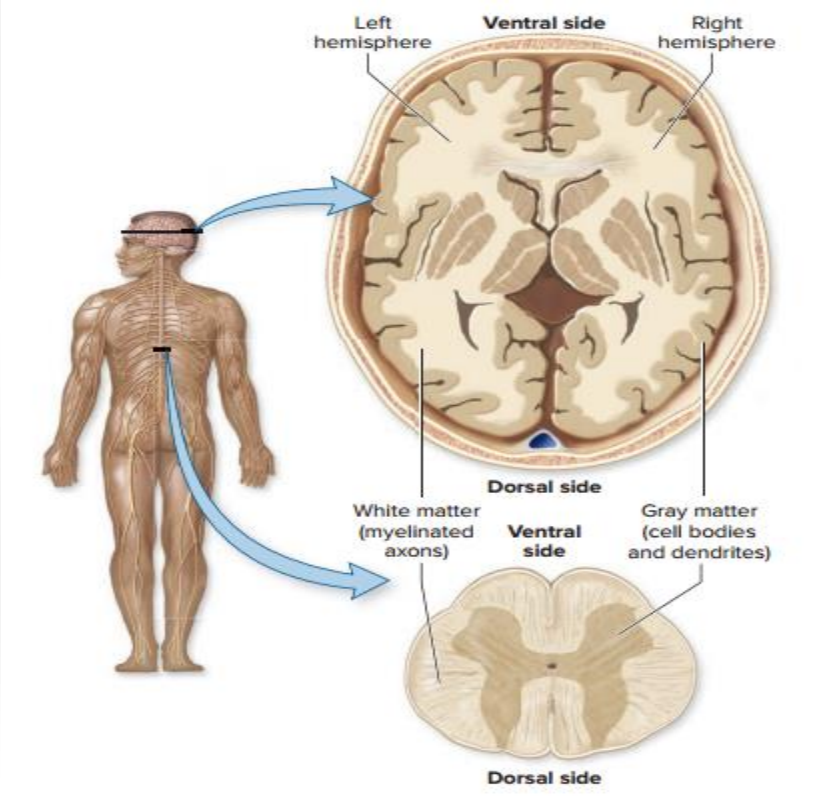


Figure 2.10 White and Gray matter of a brain

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

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 with 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 (See Figure 2.11). In the spinal cord, **the grey matter** is located in the middle, whereas the **white matter** is found on the outside (See Figure 2.12). 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.

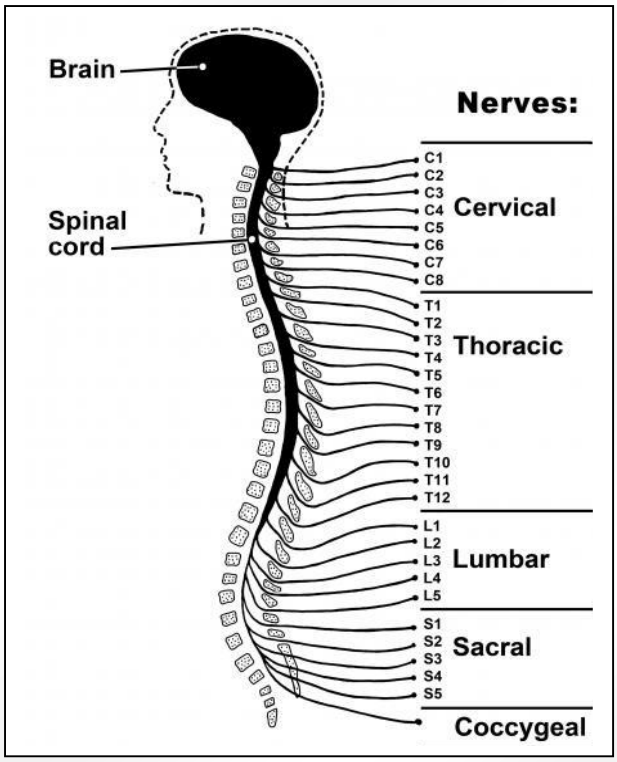


Figure 2.11 The spinal cord and spinal nerves

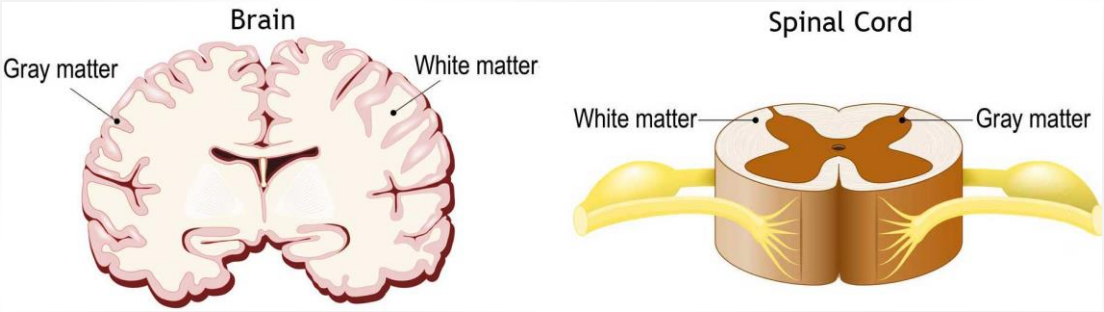


Figure 2.12 The cross-section of the CNS showing the position of grey and white matters.

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

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 that extend between the ventral and dorsal roots unto the dura mater.

Activity 2.9

Dear learner, we encourage you to understand the following:

1. Cranial and spinal nerves: Investigate the different types of cranial and spinal nerves, their names, and their roles in the human nervous system.
2. The right and left hemispheres of the brain: Delve into the functions of the right and left hemispheres of the brain, their differences, and how they work to control different aspects of your body.

B. The Peripheral Nervous System

The Peripheral Nervous System (PNS) is the division of the nervous system that contains 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 it 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.

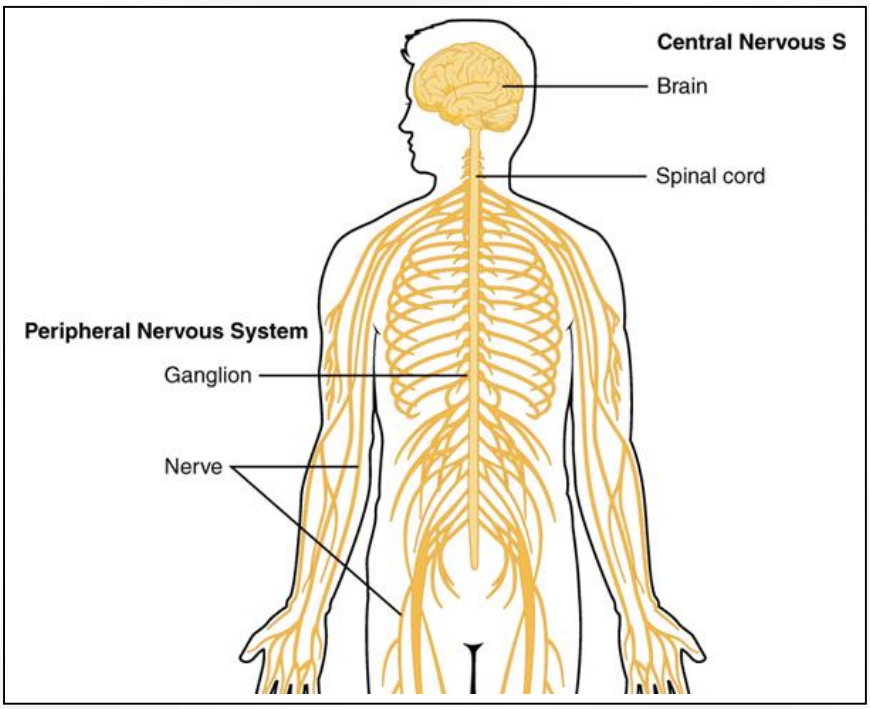


Figure 2.13 The human central and peripheral nervous systems.

A. 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 and for voluntary movement.

B. 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:

1. **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.
2. **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 of your eyes. This allows us to return our bodies to a normal resting state.

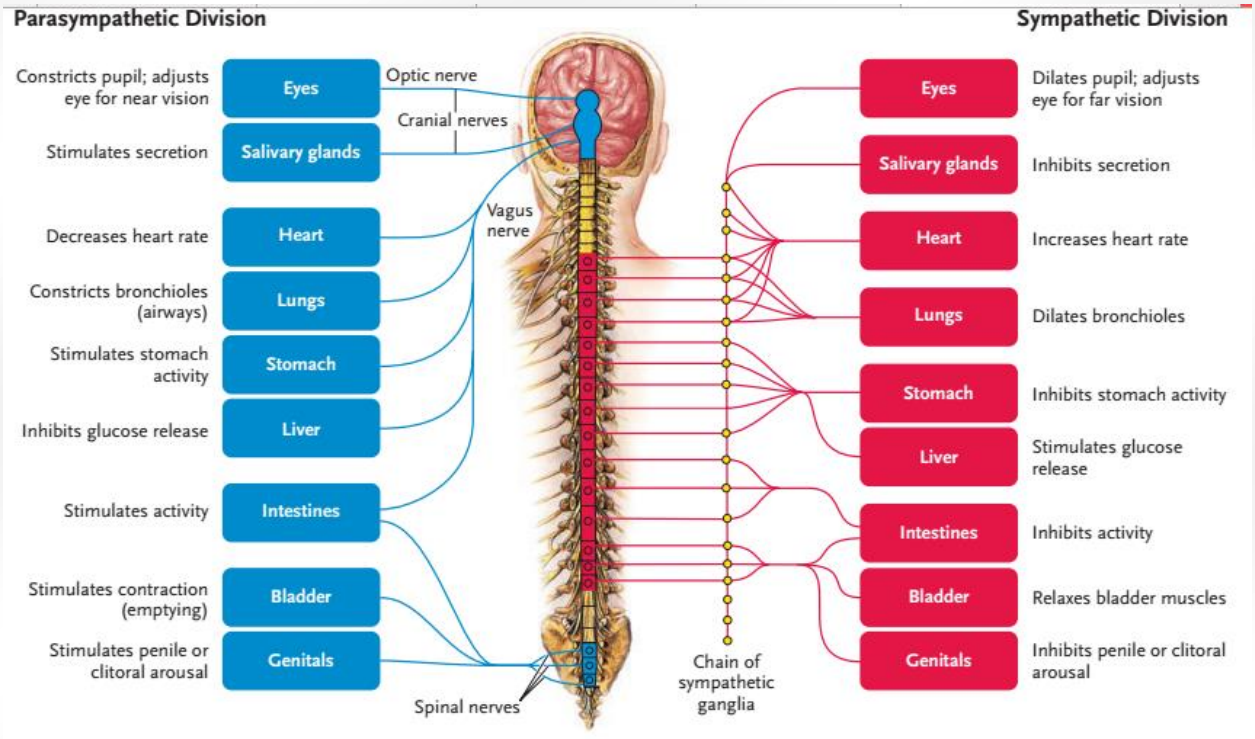


Figure 2.14 The Autonomic Nervous System

2.1.5 Reflex action

Dear learner, at the end of this section you will be able to:

- Define reflex action
- State the types of reflexes with examples.

What is a reflex action?

Keywords

Reflex action- automatic, instinctive, unlearned reactions to stimuli

Voluntary- actions that involve conscious thought

Reflex arc neural path of a reflex

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.

Activity 2.10

Dear learner,

1. Can you describe why reflexes occur so rapidly?
2. Do you believe that all reflexes are straightforward?
3. How do reflexes contribute to our safety and learning processes?
4. What differentiates voluntary actions from reflex actions?

Reflex Arc

What is a reflex arc?

Dear learner, 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-coordinating a 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 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.

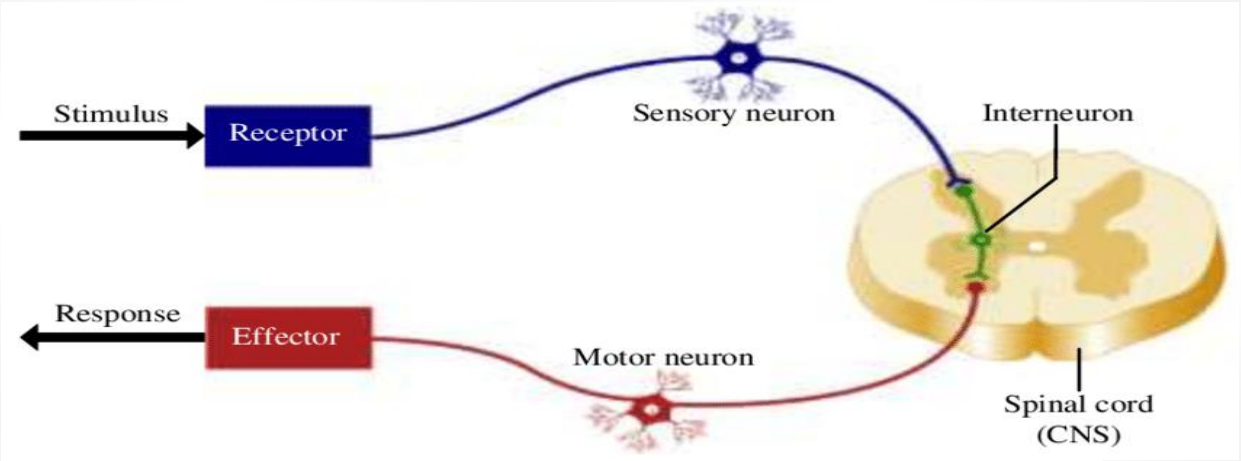


Figure 2.15 Path way for a nerve impulse in reflex action

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 as shown in the Figure 2.15:

Keywords

Dorsal root- root at the back of the spinal cord

Ventral root- root at the front of the spinal cord

- 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 sharply.

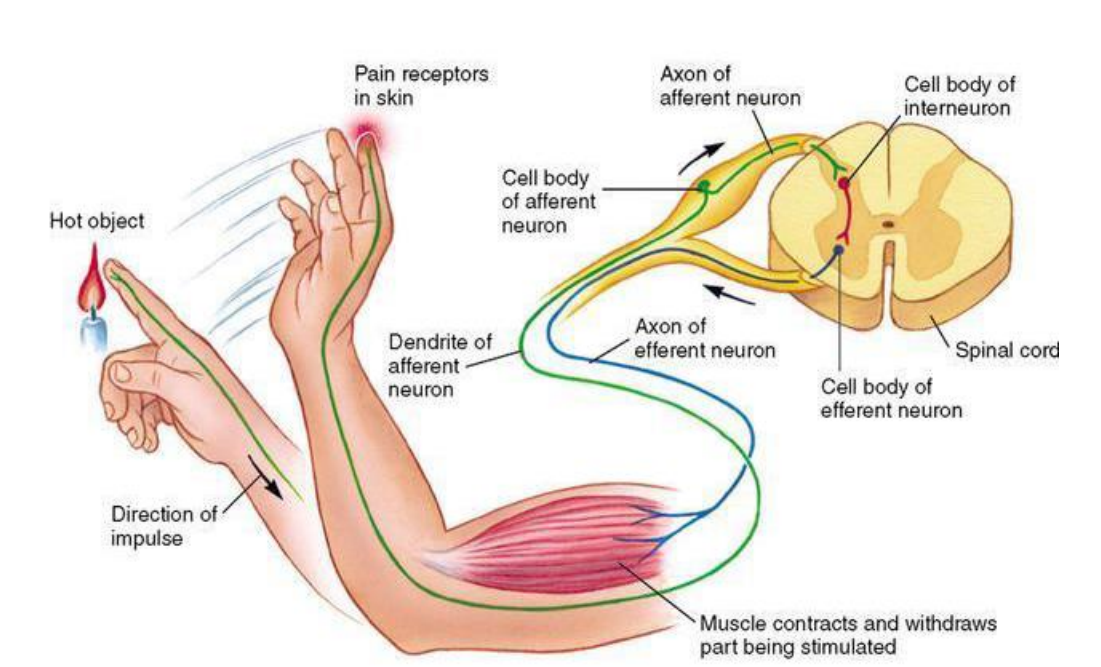


Figure 2.16 The reflex action

While some reflexes are important for avoiding injury, the knee-jerk and ankle-jerk reflexes are important for normal physiological functions. For example, the knee-jerk reflex helps a person stand erect. When the knee begins to bend slightly when a person stands still, the quadriceps femoris is stretched, and the leg straightens.

Dear learner, how do you distinguish voluntary and reflex action?

The key point about a reflex action is that 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 neurons: 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 neural pathways where receptors, neurons and effectors are involved called 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 2.11

Dear learner,

1. Can you describe Ivan Pavlov's experiment on dogs, drawing information from various sources including books and the internet?
2. Take one example of a reflex action. Draw a diagram to show this reflex arc, label it carefully and describe the reflex action.

☑ Self-evaluation checklist

Put a tick (✓) against each of the following tasks which you can perform

- Can you describe types of nervous system ☐
- Can you explain reflex action ☐
- Can you explain the types of reflexes with examples ☐

🛠 Self-test exercise

Choose the correct answer

1. Brain and the spinal cord are

A. parts of the peripheral nervous system

B. Parts of central nervous system

C. Parts of the autonomic nervous System

D. None

2. Dura mater is

A. a layer lies closest to the bone of the skull and is a double layer of tough, fibrous, connective tissue.

B. is a layer between arachoid and pia mater

C. is a delicate connective tissue layer that clings tightly to the brain.

D. is a layer that contains many tiny blood vessels that serve the brain.

3. The largest portion of the brain is

A. Cerebrum

B. Cereblum

C. Medulla oblongata

D. Thalamus

4. One of the following contains a number of reflex centers for regulating heartbeat, breathing, and blood pressure.

A. Cerebrum

B. Cerebellum

C. Medulla oblongata

D. Thalamus

5. One of the following is NOT correct about te peripheral nervous system

A. The Peripheral Nervous System (PNS) is the division of the nervous system that contains all the nerves that lie outside of the central nervous system.

B.The peripheral nervous system is subdivided into the afferent division and the efferent division .

C. The afferent division of the PNS carries signals to the CNS and it includes all the neurons that transmit sensory information from their receptors.

D. The afferent division of the PNS carries signals from the CNS to the muscles and glands, which act as effectors to bring about the desired response.

6. One of the following is NOT true about the spinal cord

A. The spinal cord has a much simpler structure than the brain.

B. The spinal cord runs out from the brain down the body.

C. The majority of nerves in the nervous system come out of the spinal cord

D. In the spinal cord, white matter is located in the middle, whereas the the grey matter is found on the outside.

7. The Autonomic Nervous System is

A**.** part of the peripheral nervous system that is responsible for transmitting sensory information and for voluntary movement.

B. part of peripheral nervous system that is responsible for regulating involuntary body functions

C. part of central nervous system that is responsible for regulating involuntary body functions.

D. part of the centrall nervous system that is responsible for transmitting sensory information and for voluntary movement

8. A reflex action is

A. an automatic response to a stimulus that provides a means of rapidly integrating and co-coordinating a stimulus with the response of an effector

B. an automatic response to a stimulus without the need for thought or a decision

C. uncontrolled response of parts of the body or the whole body to the external stimuli

D. all

9. A pathway that nerve impulses travel when a reflex is elicited is

A. reflex action

B. reflex arc

C. reflex

D. All

10. The part of the body that integrates the information it receives from all over the body in order to make decisions is

A. peripheral nervous system

B. sympathetic nervous system

C. parasympathetic nervous sytem

D. central nervous system

2.1.6 Drug abuse

Dear learner, at the end of this section you will be able to:

- Illustrate the effects of drug abuse on nervous systems with local and international examples.

What are drugs?

Dear learner, 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

Activity 2.12

Dear learner,

Dear learner,

1. How would you characterize a drug?
2. Could you define the following:
   a. What does drug use mean?
   b. What does drug abuse mean?
   c. What does drug dependence mean?

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, while some of these substances are socially acceptable, 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 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 refers to the use of a substance to the extent that affects the brain and/or body function and mental activity.

Legal drugs are used for the mild feelings of pleasure, for recreational and social enjoyment. 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 2.13

Dear learner, could you explore information from various books and resources to learn more about drug addiction, drug dependence, and the symptoms associated with withdrawal?

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.

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

Drug abuse, of both legal and illegal substances has become more of a public health problem. 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 2.14

Dear learner, could you compile a list of the most commonly abused drugs or substances used 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 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. Dopamine functions as a neurotransmitter—a chemical released by neuron. Having the right amount of dopamine is important both for the body and brain. Dopamine helps nerve cells to send messages to each other. It is produced by a group of nerve cells in the middle of the brain, which 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. Consequently, people need to use more and more tobacco to get that same good feeling.

How does nicotine use lead to addiction?

Similar to other addictive drugs, nicotine releases a chemical called dopamine in the same regions of the brain. 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.

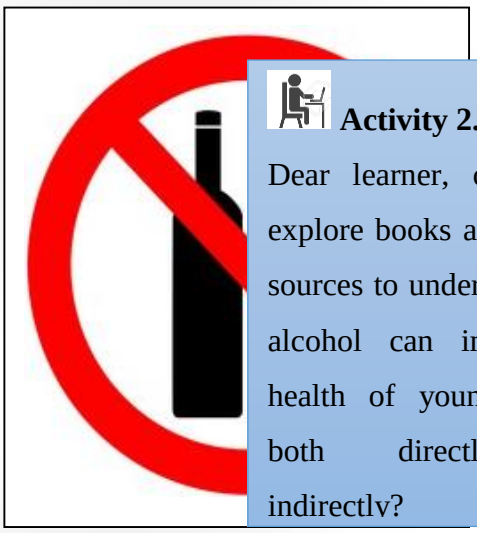
Figure 2.17 Cigarette is an addictive drug

Alcohol

Alcohol is one of the drugs most commonly used in Ethiopia. Like other drugs, alcohol 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 2.15

Dear learner, could you search about harmful chemicals found in cigarettes and the diseases caused by smoking?



Activity 2.16

Dear learner, could you explore books and various sources to understand how alcohol can impact the health of young people, both directly and indirectly?

Figure 2.18 Alcohol is addictive and poisonous

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, they feel depressed, get tired and are unable to concentrate.

Figure 2.19 A monoculture of Khat in Ethiopia

Activity 2.17

Dear learner,

1. Could you research from various sources, including books and the internet, to understand the economic significance of khat and its detrimental effects on the economy?
2. Can you enumerate some of the relationships between unprotected sex, HIV/AIDS infection, and khat? How do they interrelate?

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 responsible for memory, emotion and motivation. Cannabis is usually smoked but it can also be eaten, whenit is required to have a much stronger effect because your liver converts it into a much more powerful drug.

Activity 2.18

Dear learner, what are the health and social impacts of drug abuse on individuals, families, and communities?

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

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 in which the user sees or hears things that are not available in the real world, 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.

☑ Self-evaluation checklist

Put a tick (✓) against each of the following tasks which you can perform

- Can you describe drug abuse mean ☐
- Can you explain the effects of drug abuse on nervous systems with local and international examples ☐

🛠 Self-test exercise

Choose the correct answer

1. Drug (or substance) abuse is

A. when a person uses a substance to the point of excess and/or dependence.

B. is when a person use a drug again and again and become addicted.

C. when a person show change in behavior

D. all

2. The addictive drug in cigarette smoke is

A. nicotine

B. cathinone

C. dopamine

D. all

3. Hallocinogens

A. affect the mind in a way that produces distorted sensations abnormal in content

B. produce vivid waking dreams

C. are psychotoxic drugs

D. all

4. The addictive substance in in cannabis (marijuana) is

A. nicotine

B. cathinone

C. Tetrahydrocannabinoid (THC)

D. all

5. The nicotine in cigarette smoke

A. is harmless substance

B. causes excess release of dopamine which leads to drug dependence

C. protect the release of dopamine

D. All

Section 2.2 Sense organs

Dear learner, in the previous section, you learned about the nervous system, including its different types and some of the drugs that affect it. Now, you will move on to the structure and functions of sense organs.

Dear learner, at the end of this section, you 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

2.2.1 Skin

How does the skin work as a sense organ?

Activity 2.19

Dear learner, could you describe the functions of the 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 the 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 washing.
- 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.

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

Basic components of the human skin

With a total area of about 20 square feet, the human skin is the largest organ of the body. 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 2.20

Dear learner, could you search for a human skin model or picture and describe its basic components?

- 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 used to protect 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.

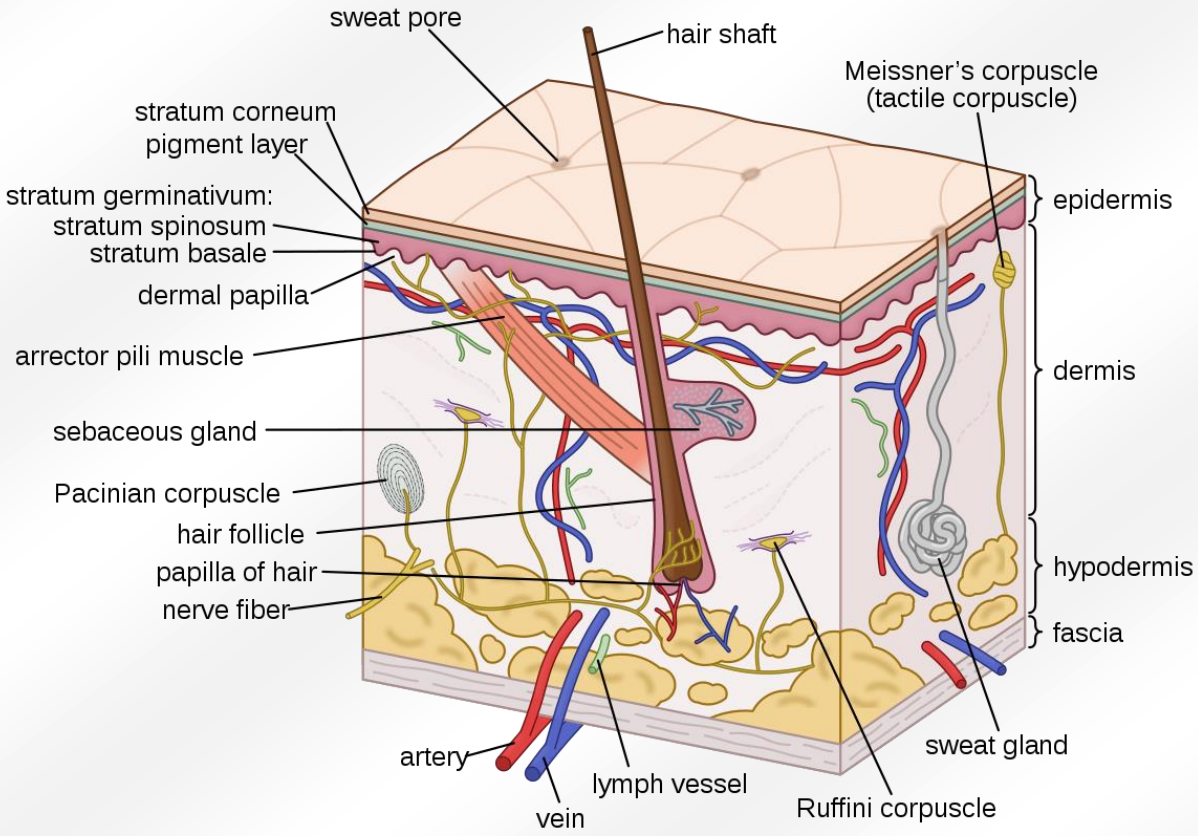


Figure 2.20 Part of the human skin

Activity 2.21

Dear learner, could you explore various sources to learn about human skin and provide explanations for the following:

1. How is human skin color influenced by a variety of pigments?
2. Could you compile a list of some common skin disorders?

2.2.2 The Tongue

How does the tongue work as a sense organ?

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 that holds down the front of the tongue is called the frenulum. 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.

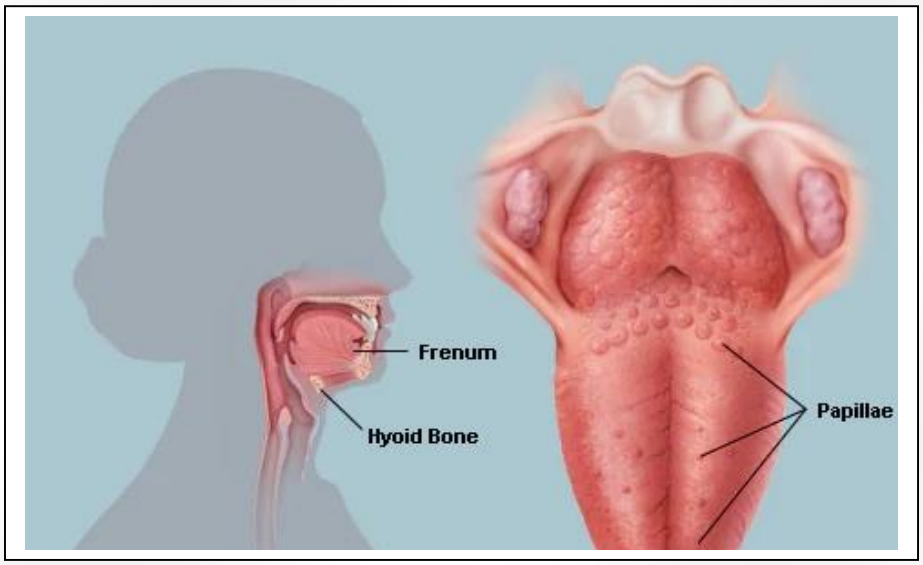


Figure 2.21 The human tongue

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 than in other areas.

Activity 2.22

Dear learner, could you explore information from different sources about the tongue and explain why there is variation in people's responses to the same stimulus?

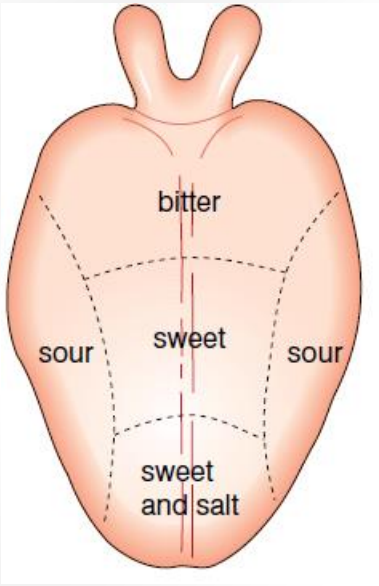


Figure 2.22 **T**he main taste areas of the tongue that has been taught for many years.

2.2.3 The Nose

How does the nose work as a sense organ?

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 signals of warnings of danger. Examples include spoiled food, fire or chemical dangers. It is one of the important means by which both humans and animals communicate with the environment. 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.

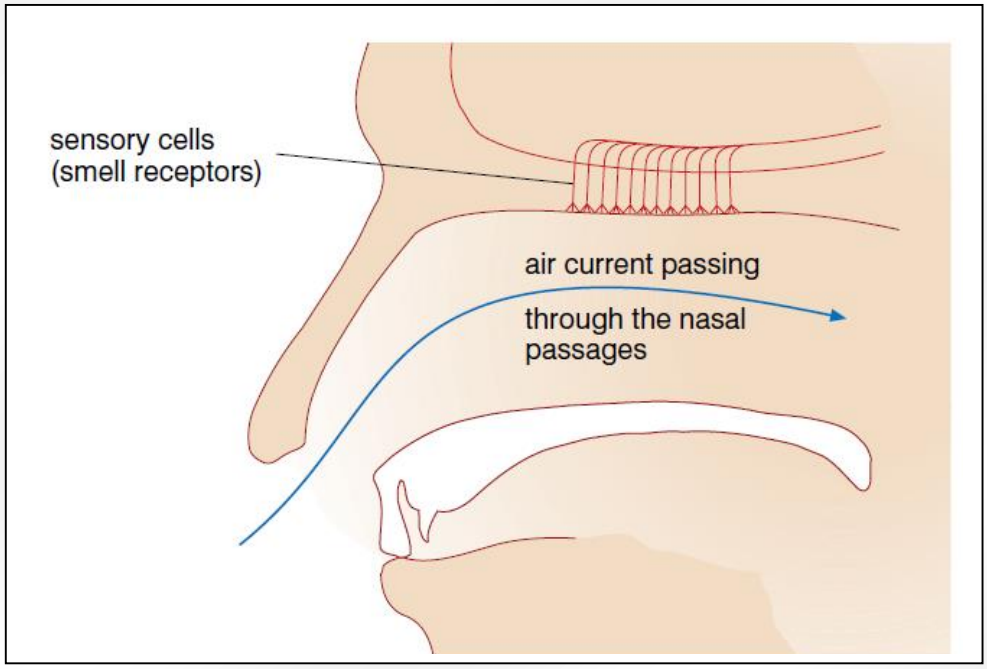


Figure 2.23 Internal structure of nose

Activity 2.23

Dear learner,

Explain why one's ability to taste foods is diminished when they have a common cold.

For human being to be able to taste and smell, chemicals must go into solution in the form of liquid that coats 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.

2.2.4 The structure, function and defects of the eye

How does the eye work as a sense organ?

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 visual fields and pathways, and the visual reflexes.

Keyword

Sensory organ an organ that receives and relays information about the body's senses to the brain

External structures of the eye

The parts of the eye that include the following are externally visible.

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 2.24). 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.

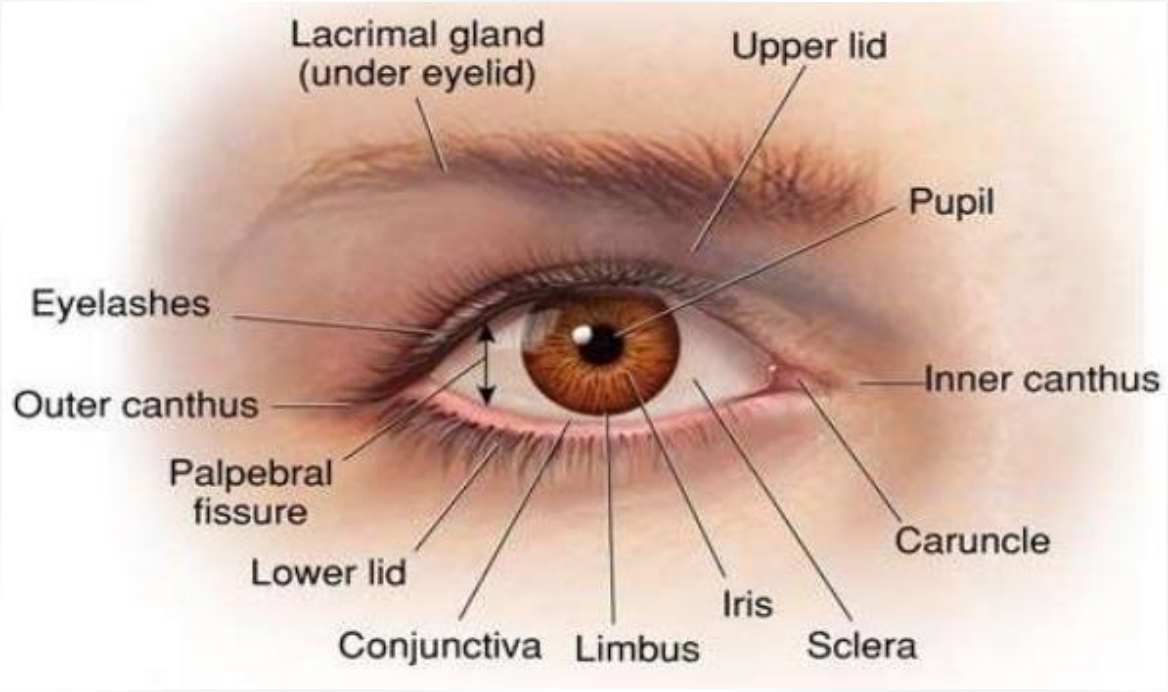


Figure 2.24 External structures of the eye

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.

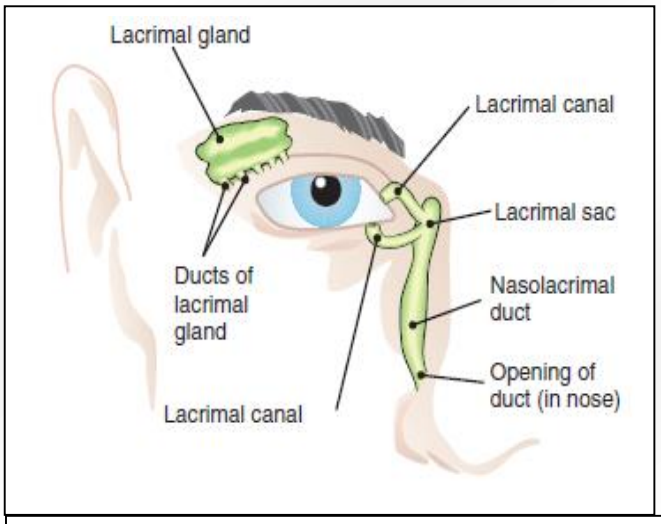


Figure 2.25 Lacrimal apparatus in the human eye

The **lacrimal apparatus** consists of glands and ducts that serve to lubricate the eye (See Figure 2.25). 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 (See Figure 2.26). These muscles control six different directions of eye movement. Four rectus muscles are responsible for straight movement, and two oblique muscles are responsible for diagonal movement.

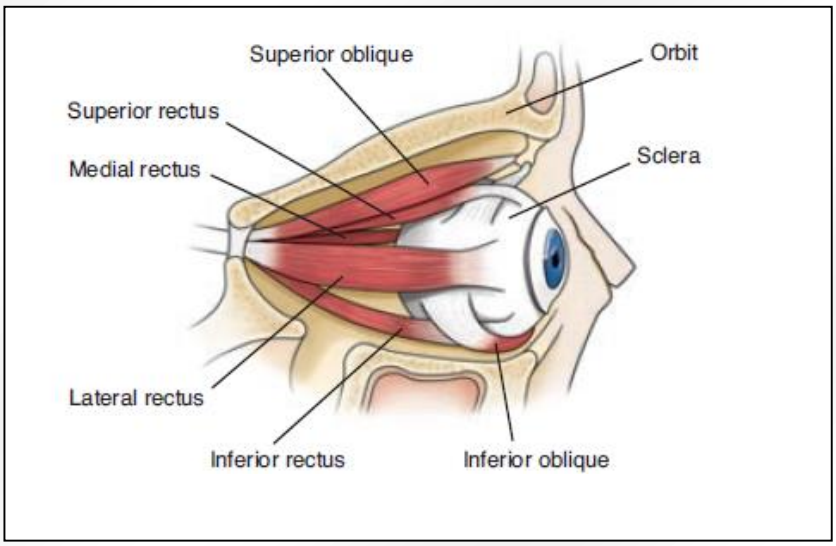


Figure 2.26 Extraocular muscles of the human eye.

Internal structure of the eye

The eyeball is composed of three separate coats or layers (See Figure 2.27). The external layer consists of the **sclera** and **cornea**.

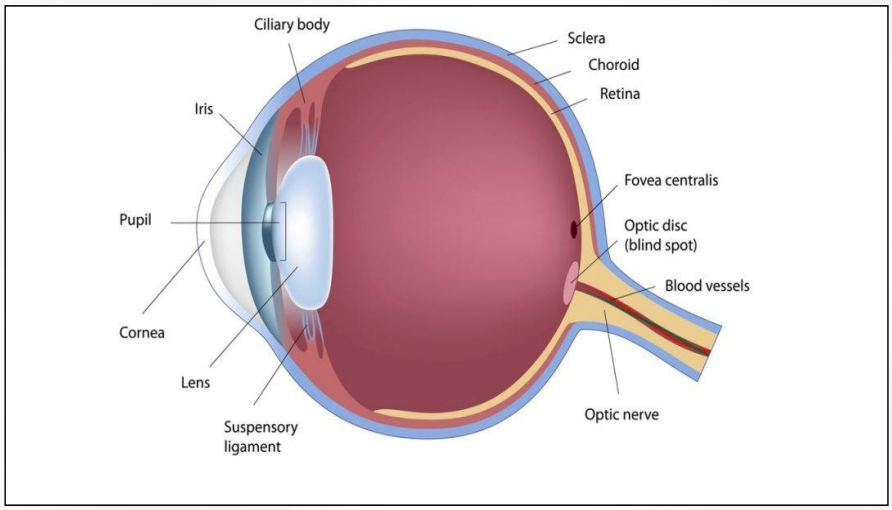


Figure 2.27 Anatomy of the human eye

- 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").
- The **cornea** which covers the pupil and the iris is the transparent, anterior or front part of our eye. 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.

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

- **Iris:** It is the pigmented, colored portion of the eye, externally visible. The main function of the iris is to control the diameter of the pupil according to the source of the light.
- **Pupil:** It is the small hole located in the centre of the Iris. It allows light to enter and focus on the retina.

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 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 2.28).

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 2.24

Dear learner

You can conduct an experiment to observe how the size of your pupils changes in response to light. Here are the steps:

1. Observe the size of your own pupils in normal working light.
2. Cover your eyes with your hands or a piece of cloth for a minute or so, keeping your eyes open normally.
3. Remove the cover from your eyes and observe the pupils closely. Note any changes immediately after removing the cover and as your eyes adjust to normal light levels.
4. Increase the light intensity by moving outside into the sunlight or nearer to windows. Again, watch and record what happens to your pupils in brighter light. Describe your observations.

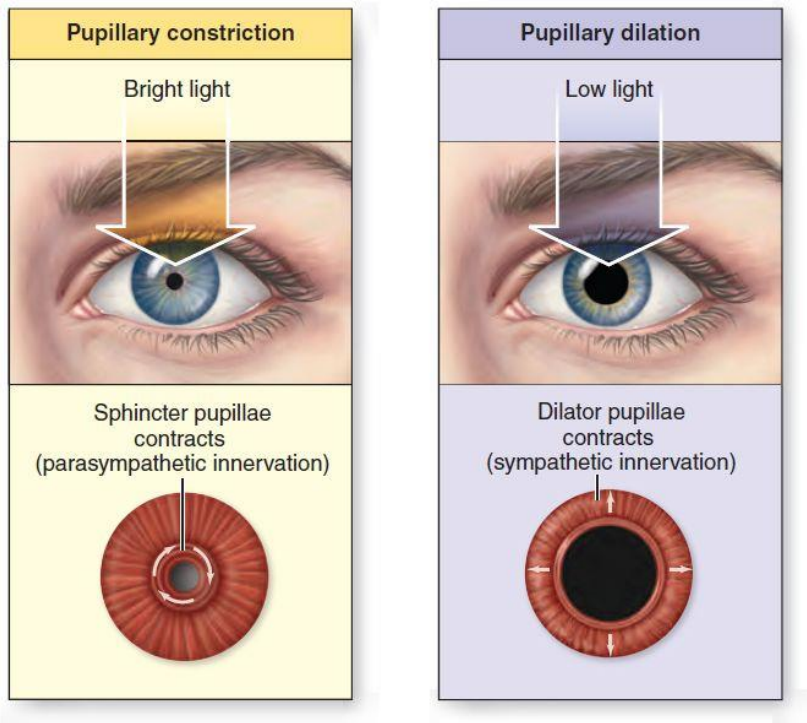


Figure 2.28 Figure showing the constriction and relaxation of pupil

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 enables the person to see. At the point where your optic nerve leaves the eye, there is no retina but there is a **blind spot**.

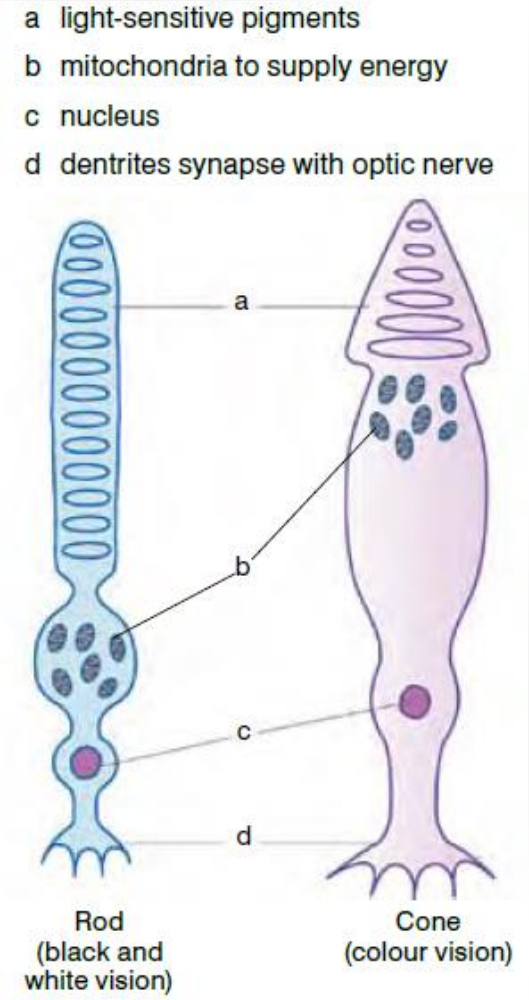


Figure 2.29 The rods and the cones in the retina of human eye

Activity 2.25

Dear learner,

1. Could you describe the retina and its function?
2. What is color blindness, and what do you believe causes it?

A retinal depression known as the **fovea centralis** (See Figure 2.29) 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 2.29). 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 2.26

Dear learner, could you investigate various soutces to explore the different types of human eye defects and potential solutions for addressing them?

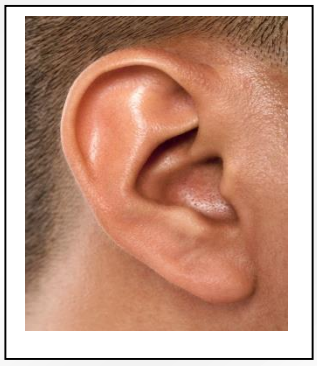
2.2.5 The structure, function, and defects of the ear

How does the ear work as a sense organ?

Activity 2.27

Dear learner, could you elaborate on the primary functions of the human ear?

Dear learner; 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 called 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**



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

Figure 2.30 The pinna of human ear

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.

What are the three tiny bones found in the middle ear?

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 2.31) 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, which is 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.

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

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 (See Figure 2.31). 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.

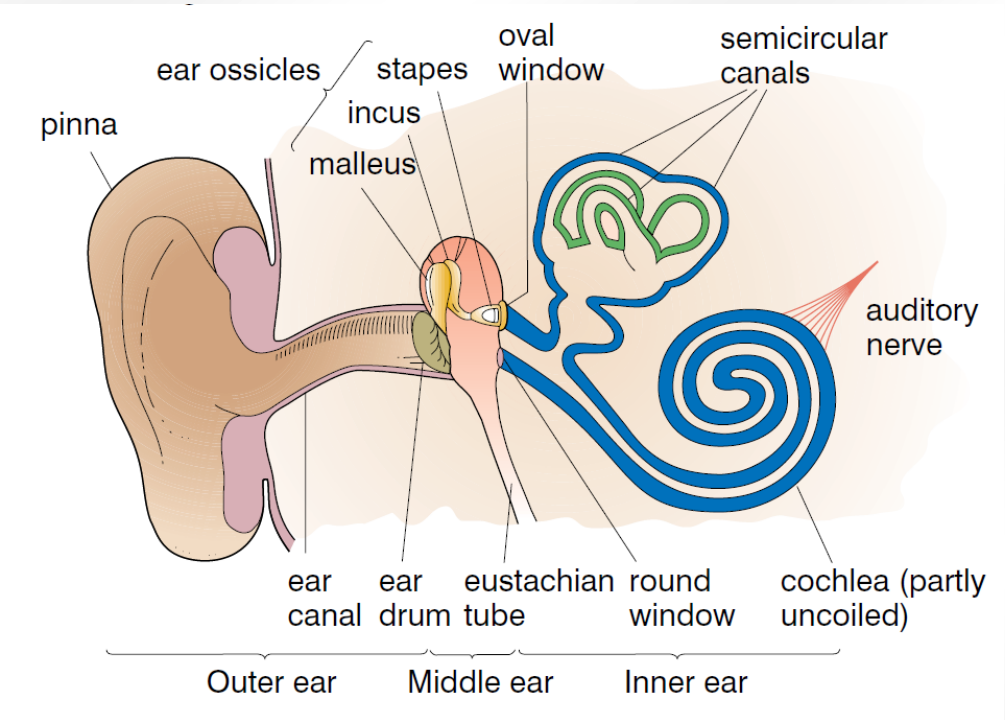


Figure 2.31

Structure of human ear

The mechanism of hearing

How do you explain the hearing mechanism?

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.

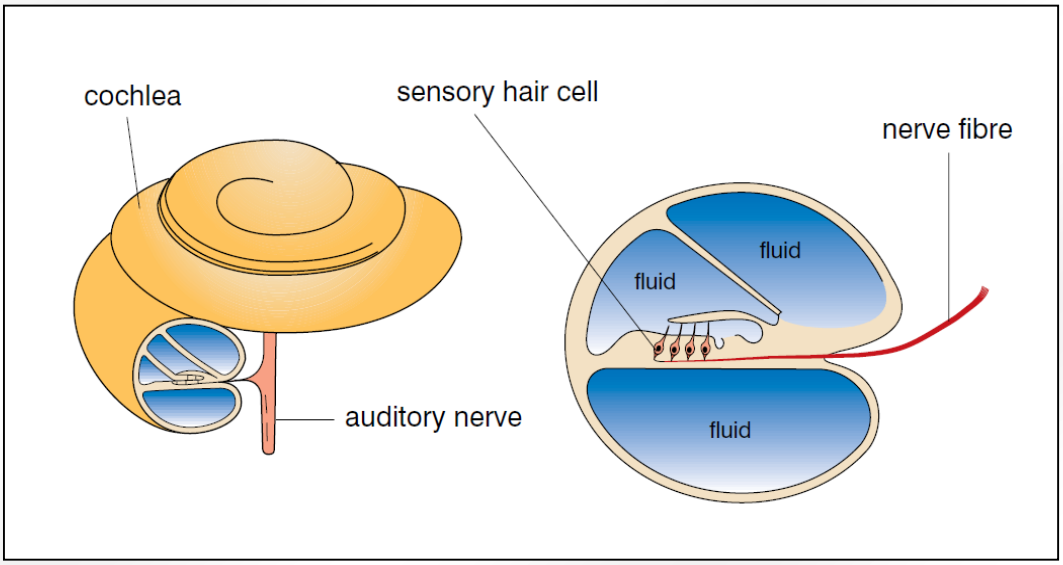


Figure 2.32 The cross section of a cochlea

The sense of balance and movement

What are the organs of balance in the inner ear?

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 (See Figure 2.32). 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

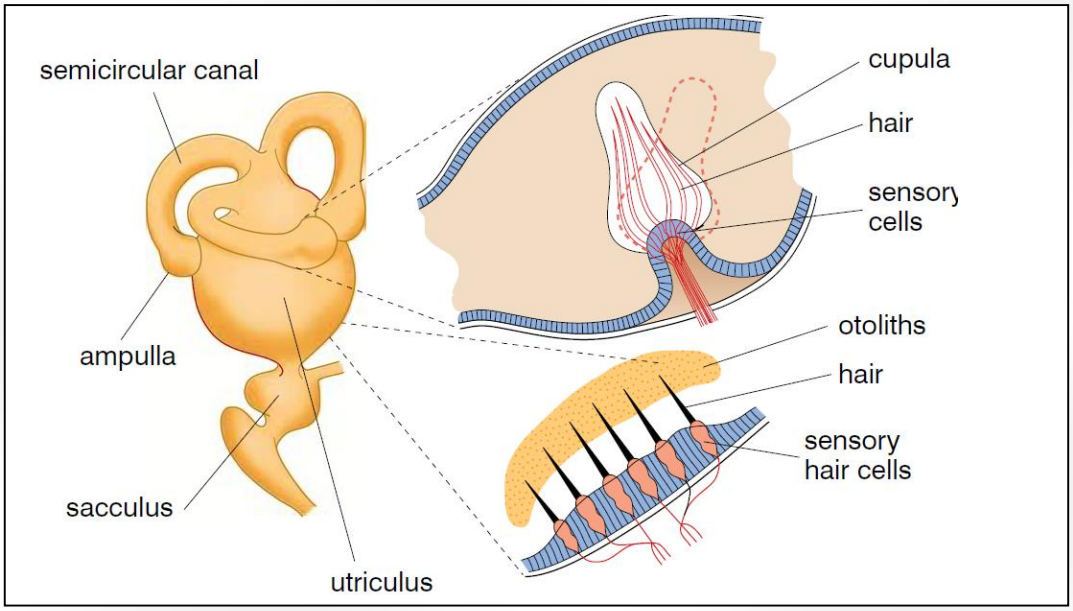


Figure 2.33 The balance organs of the ear

Activity 2.28

Dear learner, could you research various materials, including books and the internet, to comprehend the potential causes of deafness or hearing loss?

Self-evaluation checklist

Put a tick (✓) against each of the following tasks which you can perform

- Can you describe structure and function of skin ☐
- Can you explain taste sites on the tongue ☐
- Explain the structure and functions of nose ☐
- Can you explain the structure and function of the human eye ☐
- Can you explain the cmmon eye defects and their causes in humans ☐
- Can you explain the structure and functions of the human ear ☐

Self-test exercise

Choose the correct answer

1. The outermost layer of skin is

A. epidermis,

A dermis

C. hypodermis

D. All

2. Keratinocytes, melanocytes and langerhans cells are found in

A. epidermis,

A dermis

C. hypodermis

D. All

3. The sensory receptors of taste are

A. located on the upper surface of the tongue,

B. located on the lower surface of the tongue

C. located on different parts of the tongue

D. all

4. The front transparent part of the sclera is known as _____

A. Retina

B. Cones

C. Lens

C. Cornea

5. The retina features are

A. Rods

B. Cones

B. Photoreceptor cells

D. All the above options

6. Malleus (hammer), the incus (anvil) and the stapes (stirrup) are located in

A. outer ear

B. middle ear

C. inner ear

D. cochlea

7. Semicircular canals

A. are located in the inner ear and are concerned with the detection of motion.

B. are located in the middle ear and are concerned with the detection of motion.

C. are located in the outer ear and are concerned with the detection of motion.

D. all

8. A retinal depression

A. fovea centralis

B. Aqueous humour

C. vitreous chamber

D. all

9. The junction of the retina and optic nerve where sensory nerve cells are not found is known as

A. Eye spot

B. Lens Point

C. Optic junction

D. Blind spot

10. Cornea is

A. The colored part of the eye

B. The clear, dome-shaped surface that covers the front of the eye

C. The thin, blood-rich membrane that lies between the retina and the sclera

D. A bundle of nerve fibers that connect the retina with the brain

Section 2.3 The endocrine system

Dear learner, in the previous section, you learned about the structure and functions of sense organs. Now, it's time to move on to the next topic, where you will explore the location and functions of the principal endocrine glands.

Dear learner, at the end of this section, you will be able to:

- Define endocrine 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

What is endocrine system and its function?

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 that exhibits 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

Activity 2.29

Dear learner, could you describe the communication methods employed by the endocrinesystem? Additionally, can you differentiate between exocrine and endocrine glands?

The endocrine system interacts with the nervous system to coordinate and integrate body activities through **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.

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 the 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.

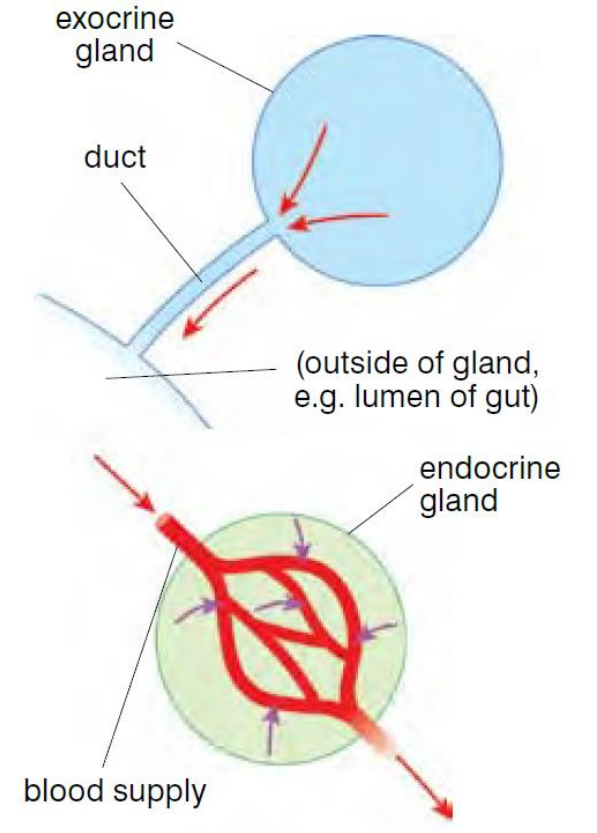


Figure 2.34 Figure showing the differences between exocrine gland and endocrine gland, and their secretions.

The major endocrine glands

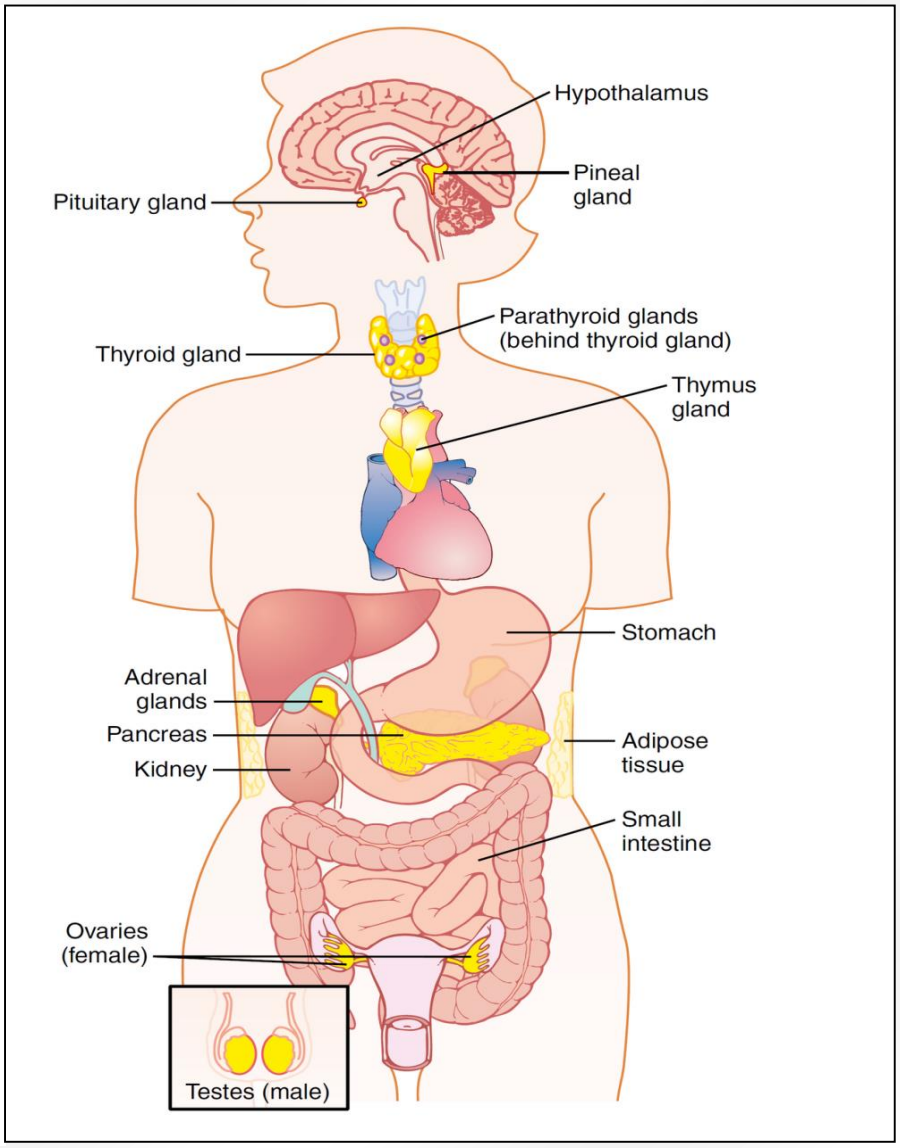


Figure 2.35 The location of endocrine glands in human body.

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.

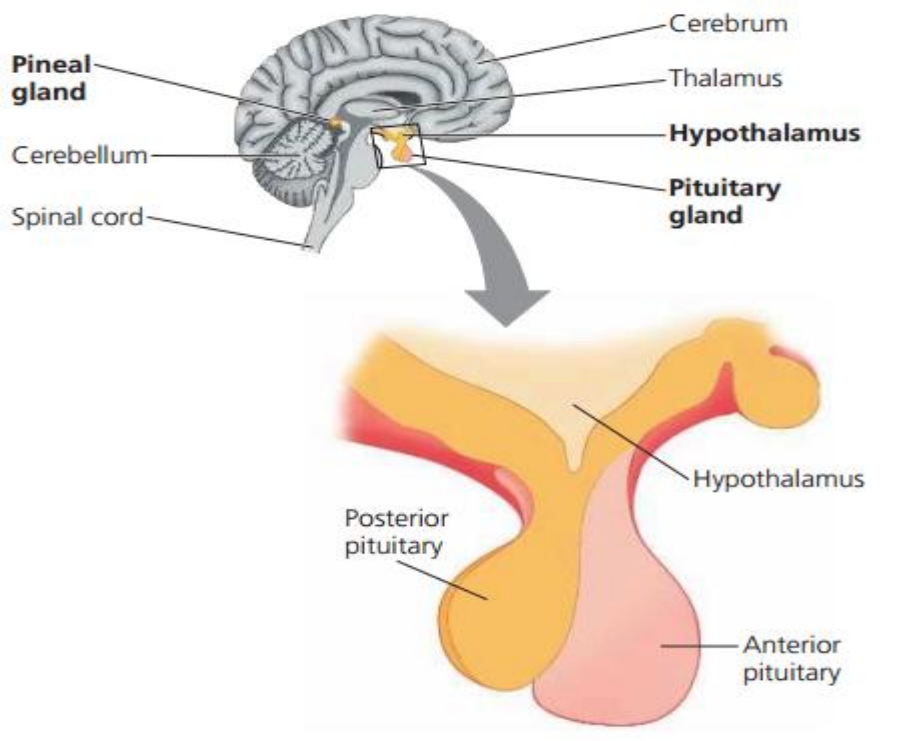


Figure 2.36 Hypothalamus and pituitary gland

The pituitary gland

Located in the brain and about the size of a pea, the pituitary gland 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, itis 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 size of 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)**:- *It* promotes the growth of the entire body by affecting protein formation, cell multiplication, and cell differentiation. Growth hormone is produced by the

anterior pituitary. The quantity of growth hormone is greatest during childhood and adolescence, when body growth mostly occurs. If too little GH is produced during childhood, the individual will have 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.

• There are two separate gonadotropic hormones, and these are follicle stimulating hormone and luteinizing hormone, which control growth of the ovaries and testes, as well as their hormonal and reproductive activities.

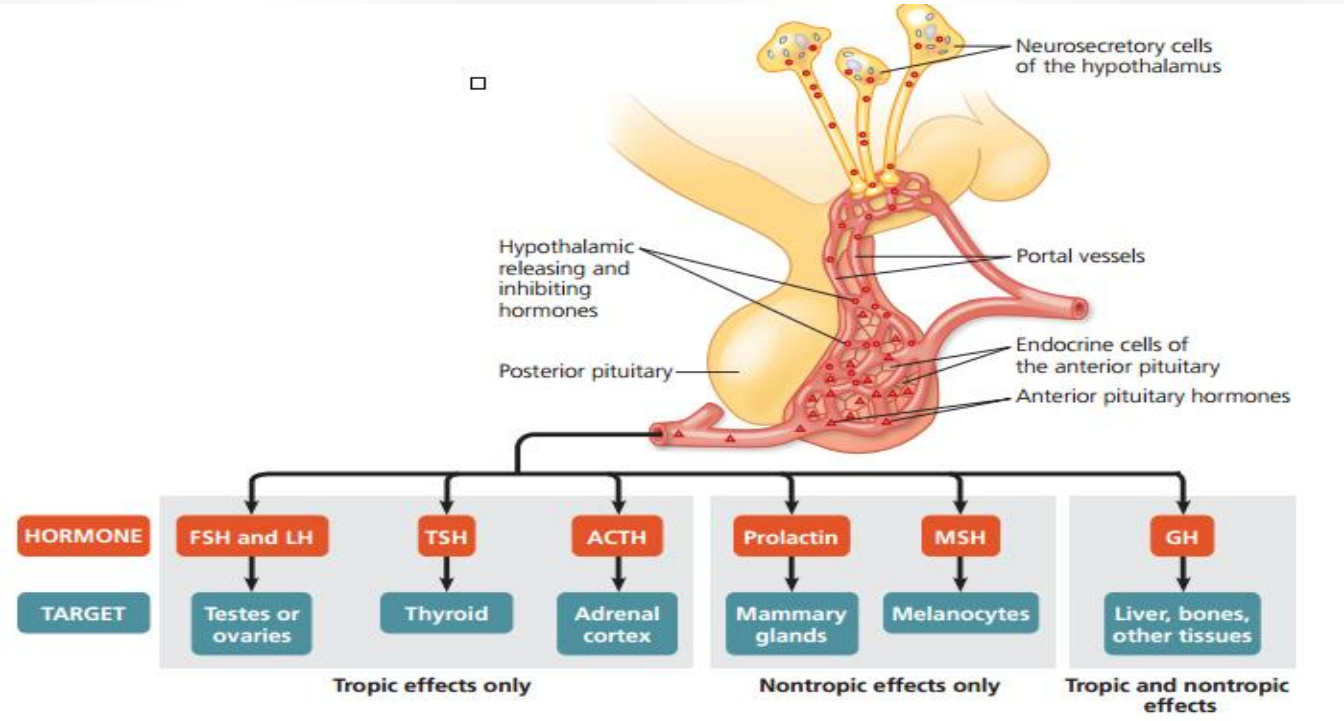


Figure 2.37 hormones secreted by anterior pituitary gland

B). Posterior pituitary gland

The posterior pituitary gland stores and releases hormones that are actually produced by the hypothalamus when needed. 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.

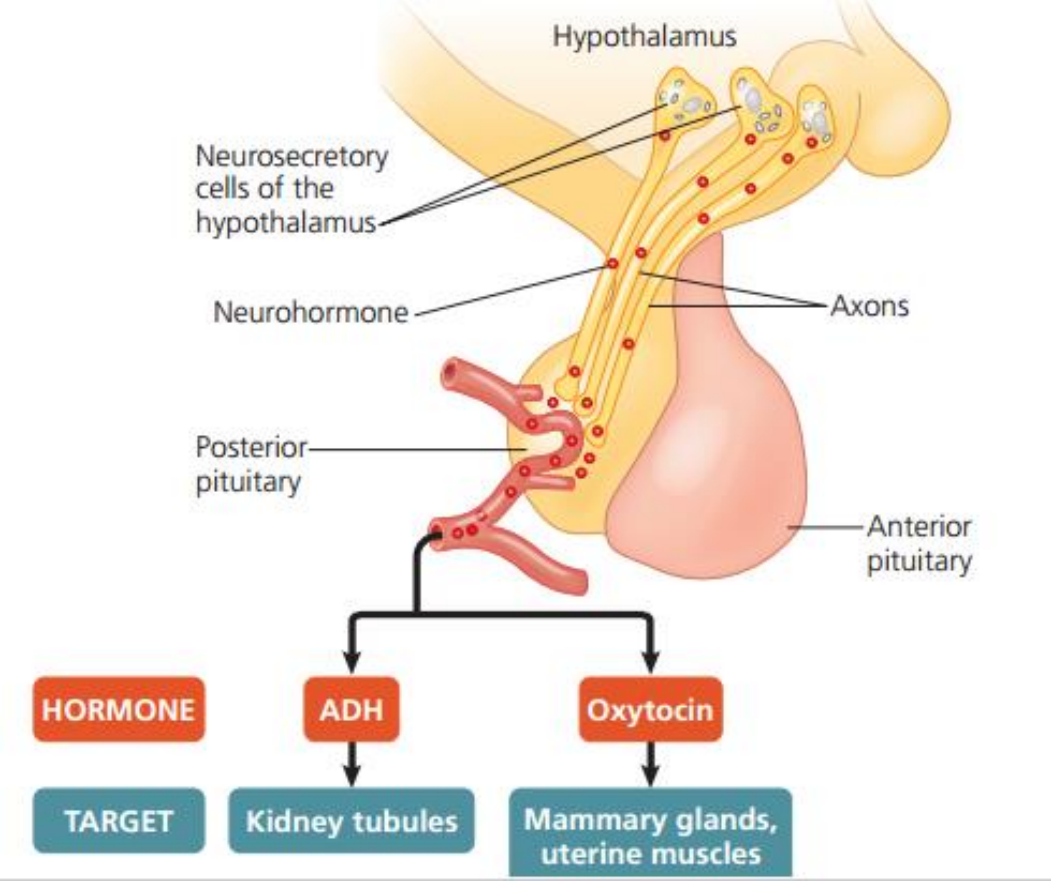


Figure 2.38 Hormones secreted by hypothalamus and stored in the posterior pituitary gland

Table 2.2 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 2.30

Dear learner, could you explore the different types of hormones produced or released by the anterior and posterior pituitary glands? Additionally, please list some of the problems associated with these hormones.

Thyroid gland

The thyroid gland (Greek thyros ,"shield") is a small, butterfly-shaped gland located below 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

Activity 2.31

Dear learner, could you please conduct research from various sources, including books and the internet, on the following topics:

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?

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.

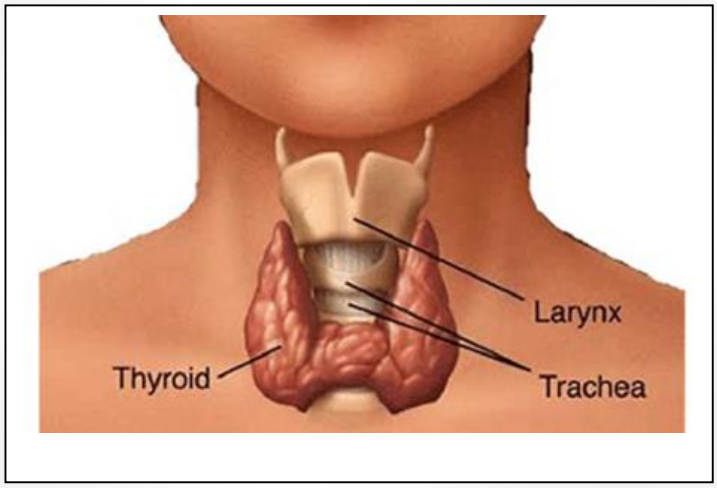


Figure 2.39 The thyroid gland

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 and leads to - a condition known as a **goiter**. In most countries, goiter is prevented through the addition of iodine to table salt.

Figure 2. 40 A woman with goiter

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.

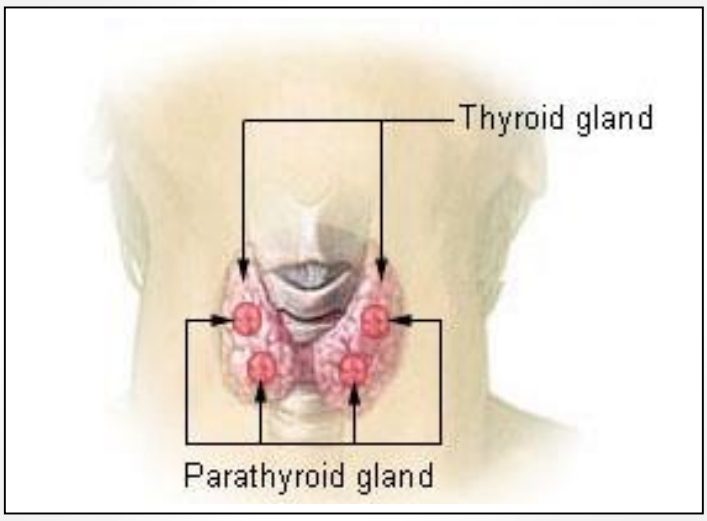


Figure 2.41 Parathyroid gland

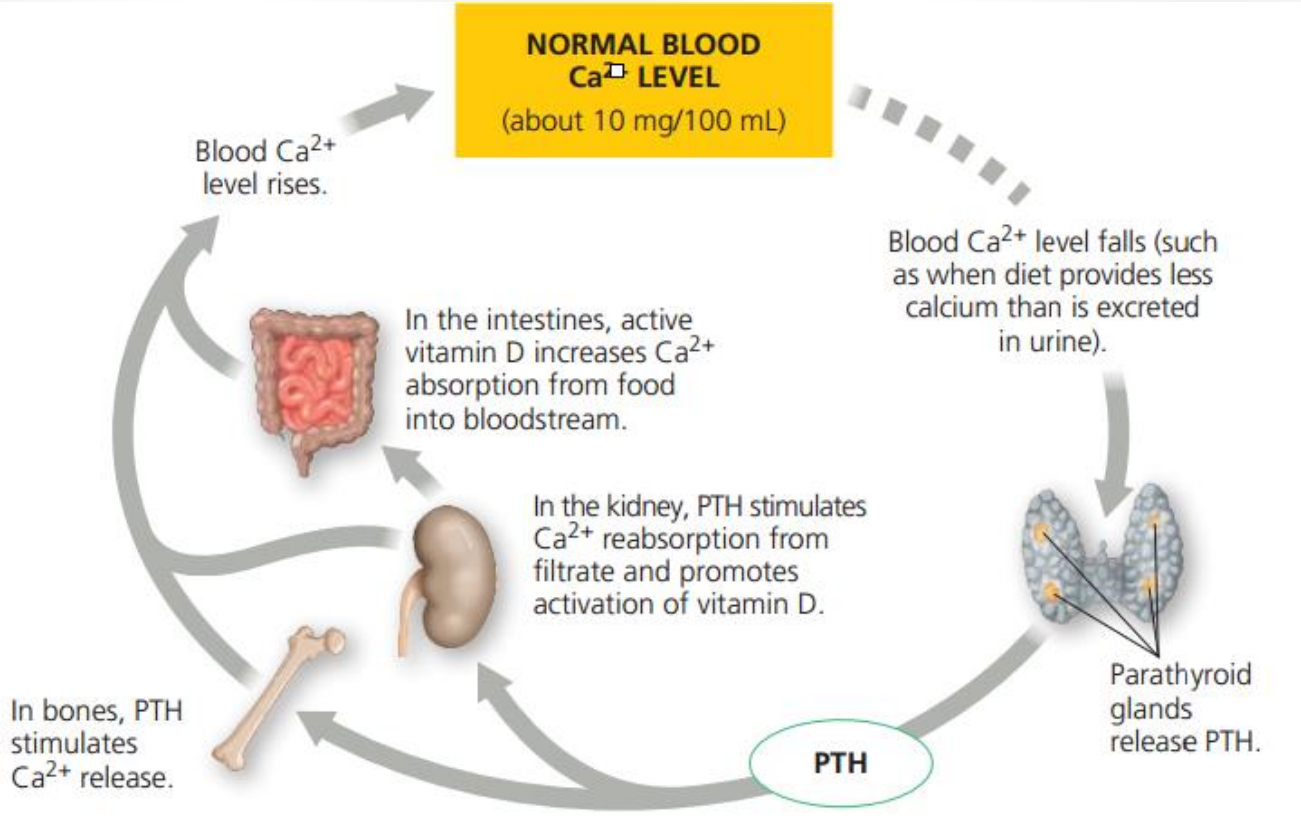


Figure. 5.42 The function of PTH in the regulation of blood calcium levels in mammals

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.

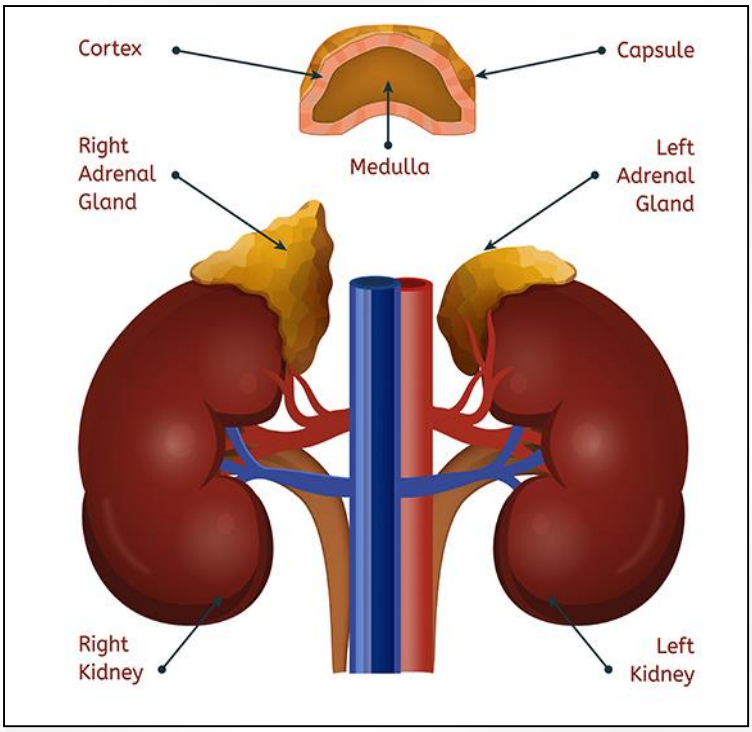


Figure 2.43 Adrenal glands

Activity 2.32

Dear learner, could you research from various sources and explore the types of hormones secreted by Zona glomerulosa, Zona fasciculata, and Zona reticularis, along with their respective roles? Additionally, please identify some of the problems associated with hypersecretion or hyposecretion of each hormone.

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. It 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 (Adrenalin speeds it up).* Adrenalin basically prepares your body for action so that you can run fast to escape or fight successfully if you need to.

Table 2.3 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 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.	ACTH (anterior pituitary) during physiological stress

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 broken down into glucose when needed by the body.

Activity 2.33

Dear learner, could you elucidate the fundamental distinctions between Type I and Type II diabetes?

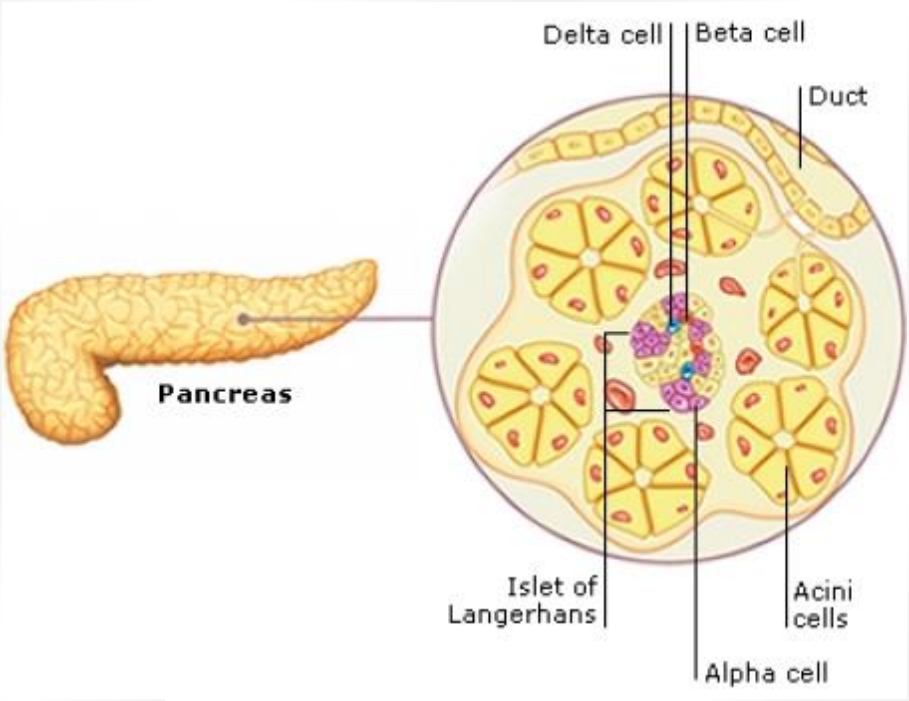


Figure 2.44 Islets of Langerhans in pancreas

A). Insulin

Insulin is well known for its effect in reducing the blood glucose levels. It does this by:

A. increasing conversion of glucose into glycogen and deposition of it in liver and muscles.

B. increasing the rate of oxidation of glucose in the tissues.

C. increasing the rate of conversion of glucose into fat and facilitates its storage in adipose tissue.

D. regulating the rate at which amino acids are catabolized into water and CO2.

Types of diabetes

Type I diabetes:- in which the pancreas can no longer manufacture insulin. It may be caused by 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 caused 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 programmed exercise 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.

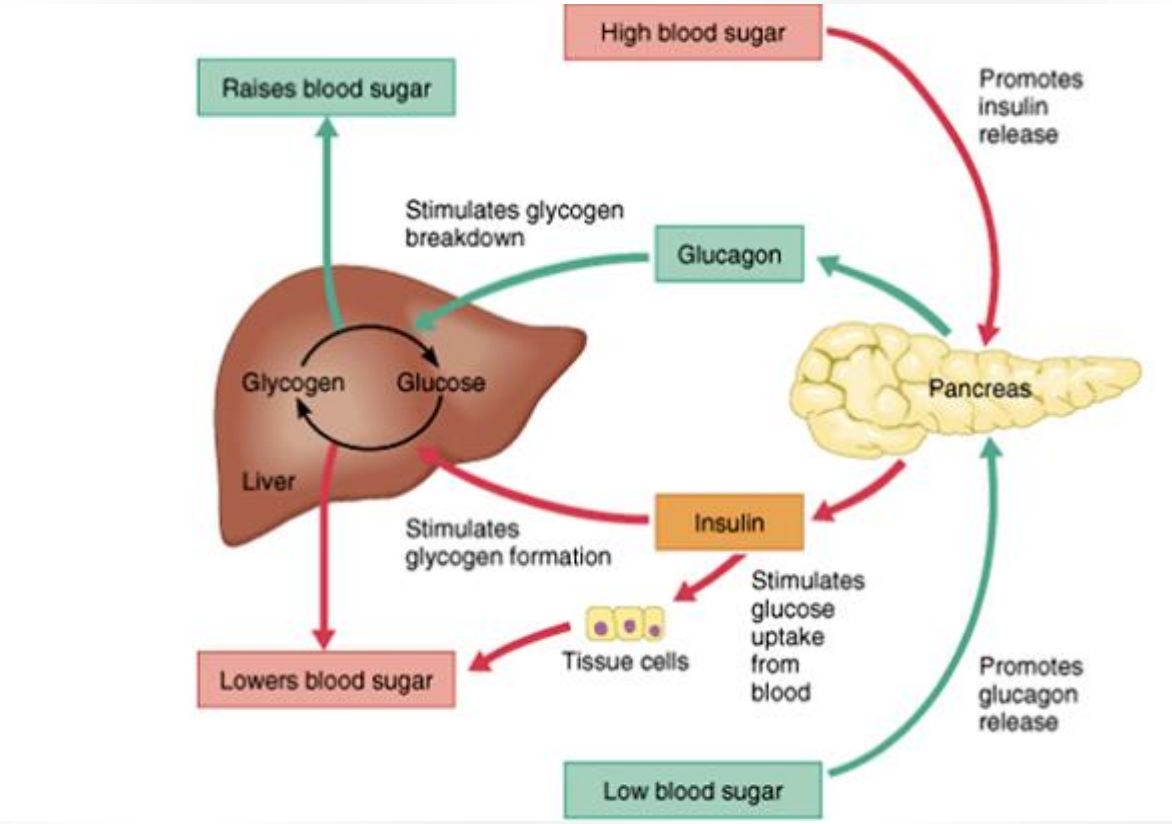


Figure 2. 45 Regulation of blood sugar level

The gonads: Ovary and testis

Activity 2.34

Dear learner, could you describe the factors that contribute to the development of secondary sexual characteristics 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 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.

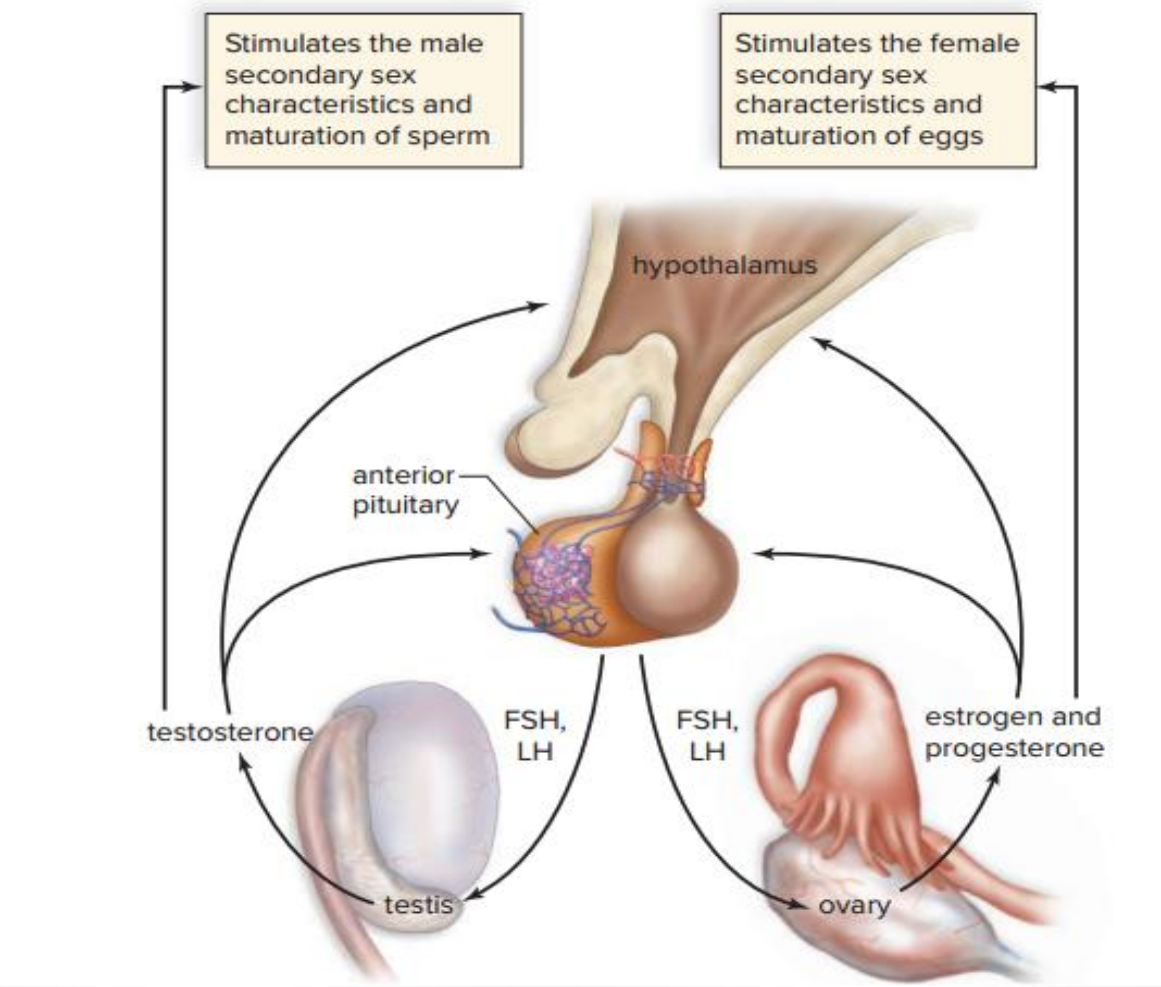


Figure 2.46 The hormones produced by the testes and the ovaries

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. Like 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 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.

Activity 2.35

Dear learner, Could you read from various books and sources about the hormones that influence the female reproductive system, as well as their role in controlling the menstrual cycle and fertility?

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 begin to 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 the 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 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 2.47 hormones secreted by ovaries and testes

Pineal gland

Pineal gland is pine cone shaped gland 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.

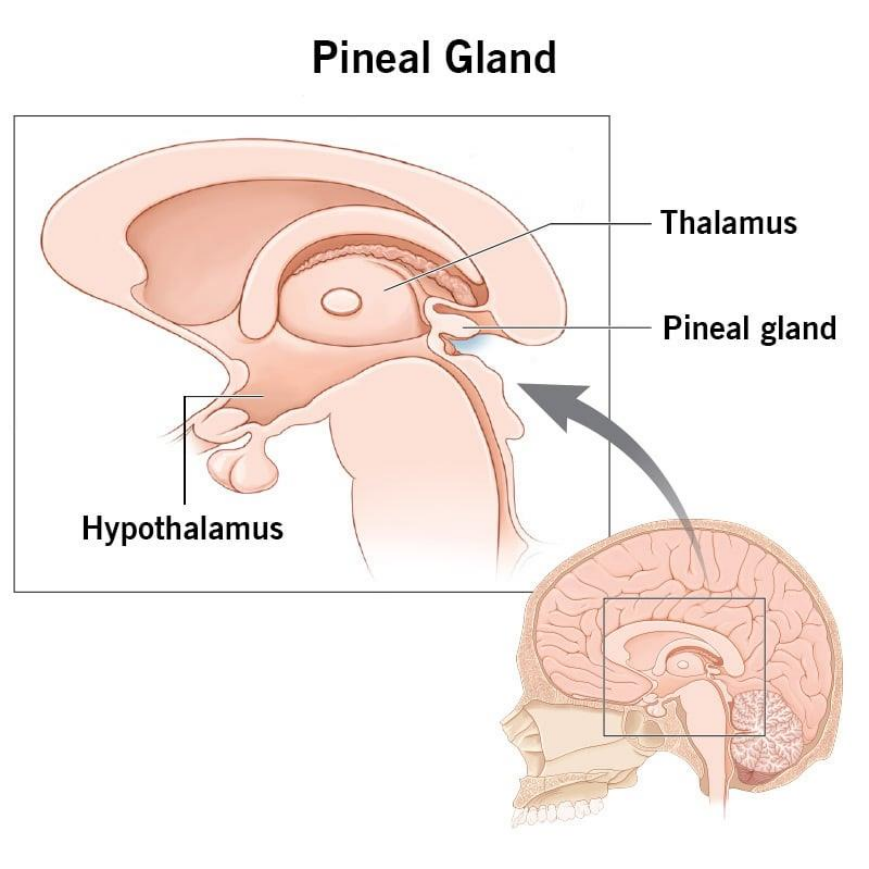


Figure 2.48 Pineal gland

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, the 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

.

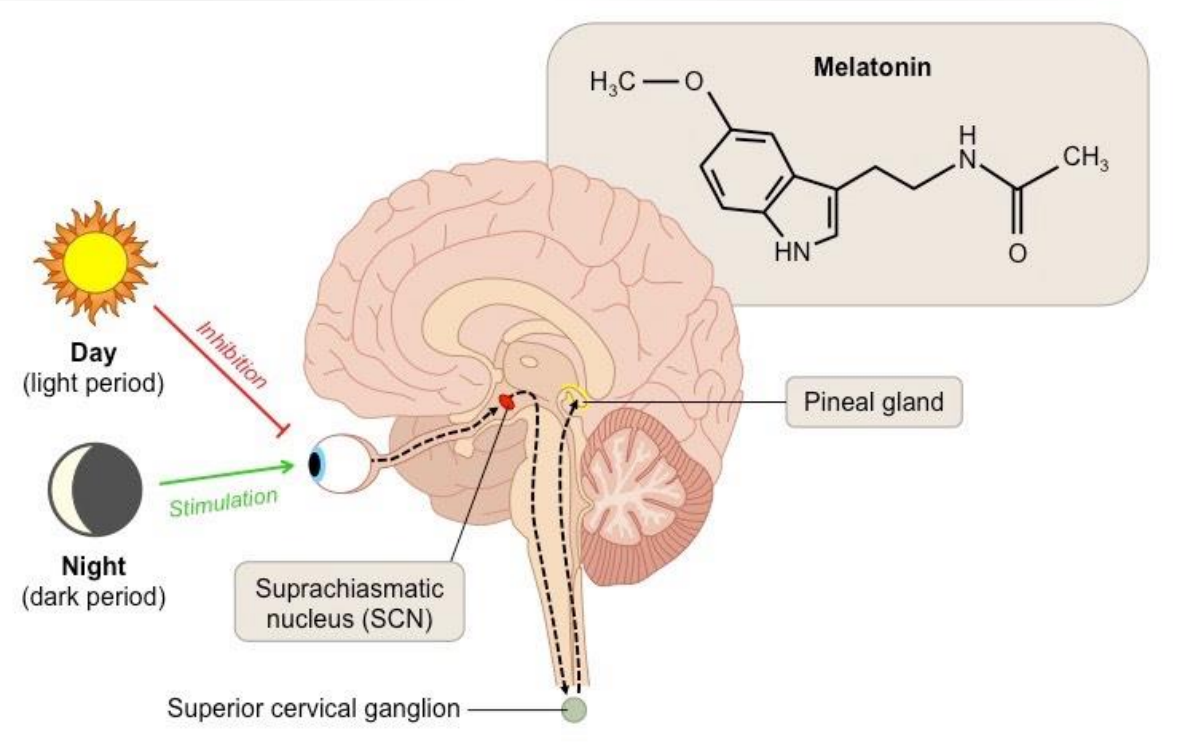


Figure 2.49 Pineal gland

Thymus gland

A thymus gland is a diminishing gland (over time) located between the lungs. It secretes a group of hormones, such as **thymosin** that affects the production and maturation of lymphocytes in body defenses.

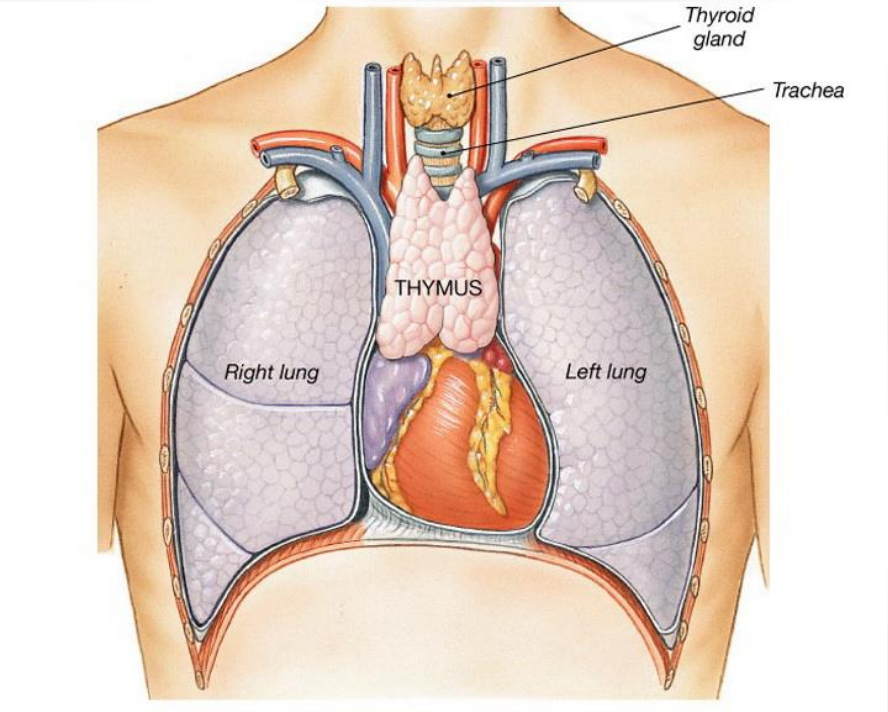


Figure 2.50 Thymus gland

Self-evaluation checklist

Put a tick (✓) against each of the following tasks which you can perform

- Can you describe the function of glands and hormones ☐
- Can you compare and contrast exocrine and endocrine ☐
- Can you identify the location and function of principal endocrine glands such as pituitary, thyroid, parathyroid, adrenal, and pancreas gland ☐

Answer the following questions

1. Endocrine glands _____.

a. secrete hormones that travel through a duct to the target organs
b. release neurotransmitters into the synaptic cleft
c. secrete chemical messengers that travel in the blood stream
d. include sebaceous glands and sweat glands

2. Which of the following is an anterior pituitary hormone?

a. ADH

b. oxytocin
c. TSH
d. all

3. Which of the following hormones contributes to the regulation of the body's fluid and electrolyte balance?

a. adrenocorticotropic hormone
b. antidiuretic hormone
c. luteinizing hormone
d. all of the above

4. Which of the following statement is true about the thyroid gland ?

a. It is located anterior to the trachea and inferior to the larynx.
b. The parathyroid glands are embedded within it.
c. It manufactures three hormones.
d. all of the above

5. The secretion of thyroid hormones is controlled by _____.

a. TSH from the hypothalamus
b. TSH from the anterior pituitary
c. thyroxine from the anterior pituitary
d. thyroglobulin from the thyroid's parafollicular cells

6. The development of a goiter indicates that _____.

a. the anterior pituitary is abnormally enlarged
b. there is hypertrophy of the thyroid's follicle cells
c. there is an excessive accumulation of colloid in the thyroid follicles
d. the anterior pituitary is secreting excessive growth hormone

7. Which of the following can result from hyperparathyroidism?

a. increased bone deposition
b. fractures
c. convulsions

d. all of the above

8. The adrenal glands are attached superiorly to which organ?

a. thyroid
b. liver
c. kidneys
d. hypothalamus

9. The secretion of strogen is stimulated by

a. Thyroxine
b. progesterone
c. FSH
d. inhibin

10. Which of the following statements is true about insulin?

a. Insulin acts as a transport protein for glucose across the cell membrane.
b. Isulin allows your body to use glucose.
c. Insulin stimulates the breakdown of stored glycogen into glucose.
d. all

Section 2.4 Homeostasis in the human body

Dear learner, in the previous section you learned about the location and functions of principal endocrine glands. Next, in this section, you will learn about homeostasis, the regulatory mechanisms of body temperature, sugar level, water balance, and the structures and functions of the human kidney and liver.

Dear learner, at the end of this section you 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

2.4.1 The structure and function of the human kidney

What are the vital functions of human kidney?

The kidneys are a pair of bean-shaped organs just above the waist. They are important organs that have 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.

Activity 2.36

Dear learner, could you explain how the kidneys regulate 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.

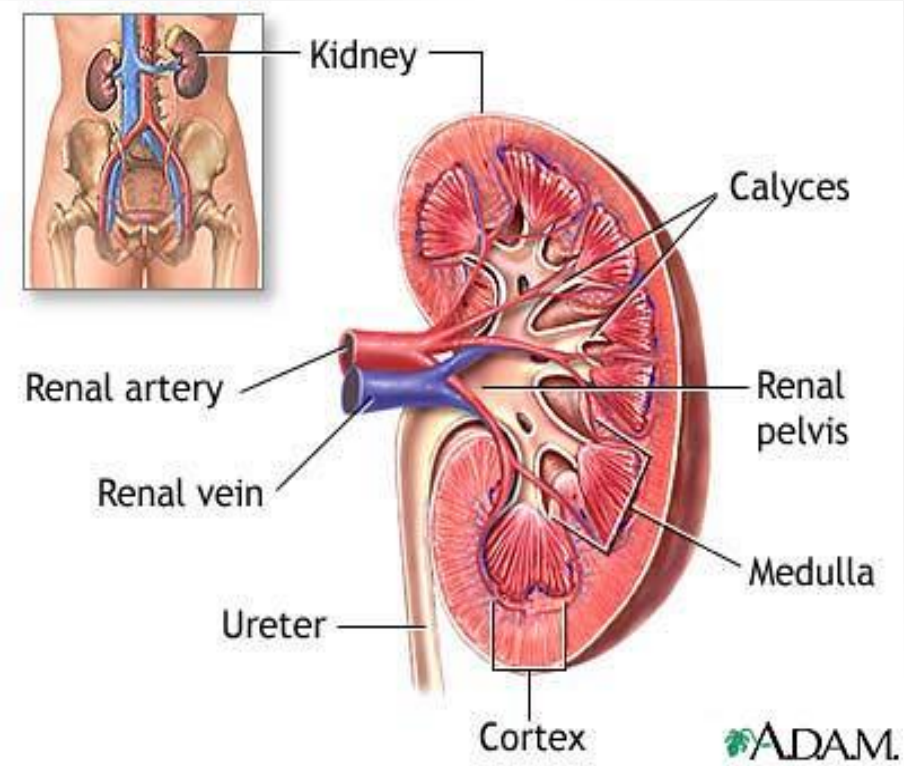


Figure 2.51 The anatomy of human kidneys

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 liquid substances 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.This is a measure of the liquid which has moved into the capsule as a result of ultrafiltration.

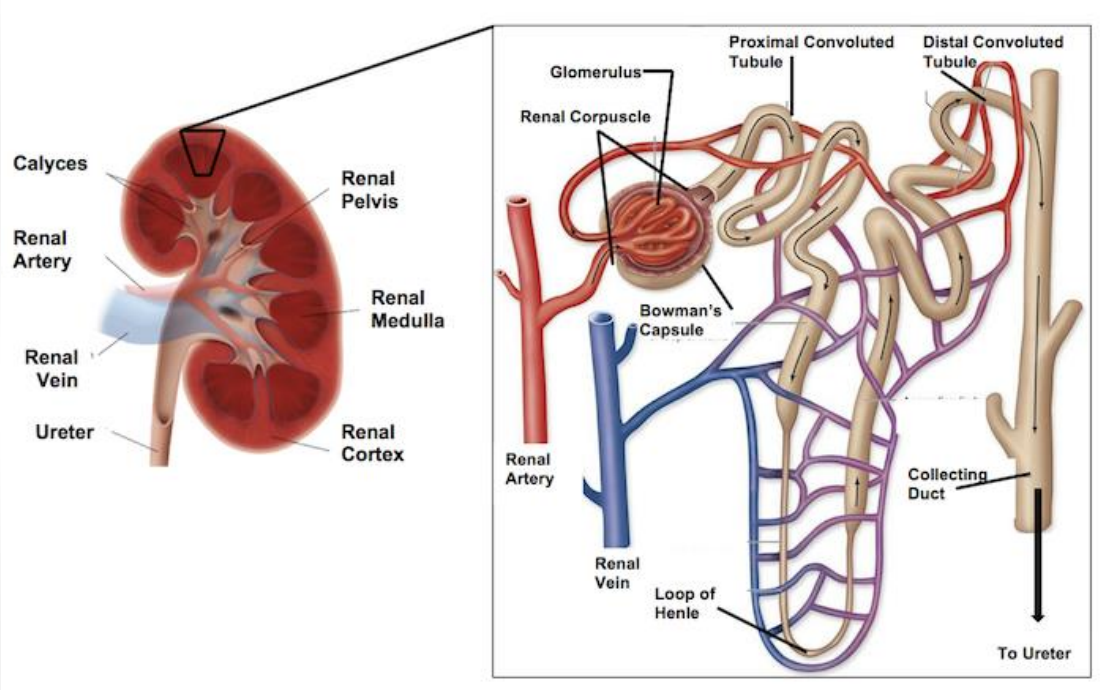


Figure 2.52 The kidney filters the blood and removes waste materials.

- **First coiled (convoluted) tubule:** This is the liquid which enters the first tubule, which is known as the glomerular filtrate. The first tubule is an area 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 water 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.) Ammonium ions and some drugs (if they have been taken into the body) are also 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:It** 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 be collected 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 that involves 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 that make them more permeable so that more water is reabsorbed back into the blood.

  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 of urine. So more than 99% of the liquid filtered out of the blood is eventually returned to kidney.

2.4.2 Thermoregulation

What is thermoregulation?

Dear learner, thermoregulation is a mechanism by which mammals maintain body temperature with tightly controlled self-regulation independent of external temperatures It is vitally important that wherever you go and whatever you do, your body temperature is maintained at the temperature (around 37 °C) at which your 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 2.37

Dear learner, could you explore various types of books to learn about the different physiological and behavioral methods used by the human body to regulate temperature?

2.4.3 Osmoregulation

What is osmoregulation?

The maintenance of an internal balance between water and dissolved materials regardless of environmental conditions is known as 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 and other days much less. How is the balance maintained?

We gain water when we drink and eat. We lose water constantly when we breathe out from the lungs, 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 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 the 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 controlling balance is wrong, 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.

Activity 2.38

Dear learner, could you investigate if there are traditional methods used in your locality to regulate body homeostasis?

2.4.4 Chemical regulation

Human liver plays a vital role in maintaining a constant internal environment. It is the largest 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 system. 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 that brings the products of digestion to the liver to be dealt with.

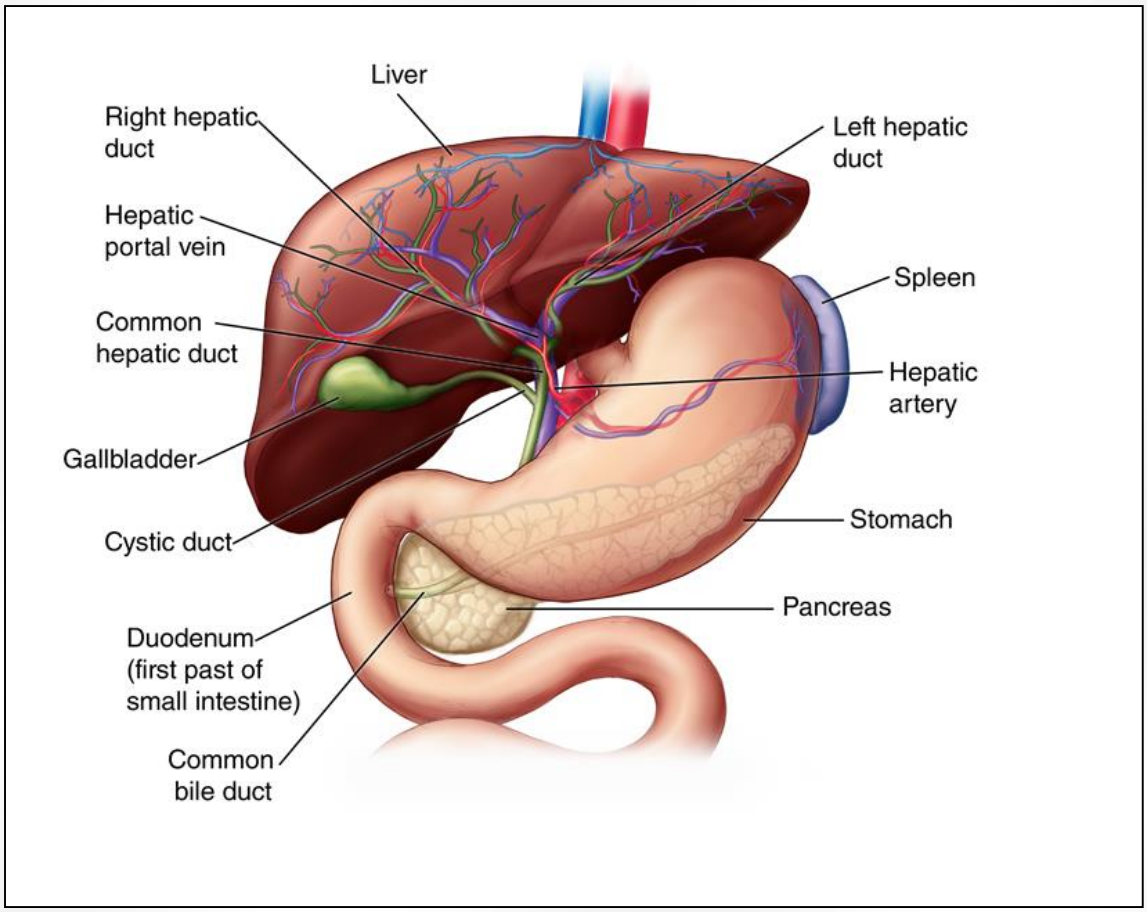


Figure 2.53 The liver is one of the most active organs in the body

A large number of reactions take place in the liver. Many of them are involved in homeostasis in one way or another. A liver 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 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 a 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 including alcohol you take into the body That 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 2.39

Dear learner, could you explore various books and materials to learn about additional types of chemical regulation occurring in the human body?

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 CO_2. (PCO_2). Changes in the levels of O_2, CO_2 and H^+ in the blood cause compensatory changes in the level of ventilation.

☑ Self-evaluation checklist

Put a tick (✓) against each of the following tasks which you can perform

- Can you explain homeostasis ☐
- Can you explain regulatory mechanisms of body temperature, sugar and water balance ☐

Answer the following questions

1. The maintenance of an organism's internal environment is called

A. Homeostasis

B. Osmosis

C. Cell transport

D. All

2. The site of the ultrafiltration of the blood in a kidney

A. Bowman's capsule

B. Glomerulus

C. Loop of Henlé

D. Convoluted tubule

3. Homeostasis in the human body is often maintained by a:

A. Negative feed back loop

B. Positive feed back loop

C. Brain loop

D. All

4. One of the following is NOT an example of homeostasis.

A. Maintaining the body temperature at 37^{o}C

B. Body regulating sugar in the body

C. Thinking

D. All

5. 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

Section 2.5 Unit Summary

❁ Dear learner, in this unit you have learnt that:

- Human beings have both nervous and hormonal co-ordination and control systems. 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.
- When someone use a substance to the point of excess and/or dependence, this excessive drug use is called drug abuse, and when an individual use a drug again and again and become addicted, the persistent use of drug called drug dependence.Drugs change the chemical processes in human body, which 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 three parts of an ear: 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.

Assignment questions

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.

Answer Key

Unit two. The Human body system

Section 2.1 (The Nervous System)

Correct answers: D-D-A-C-A-A-B-B-D-A

2.1.4 (Types of the nervous system)

Correct answers: B-A-A-C-D-D-B-D-B-D

2.1.6 (Drug abuse)

Correct answers: D-A-D-C-B

Section 2.2 (Sense organs)

Correct answers: A-A-A-B-D-B-A-A-D-B

Section 2.3 (The endocrine system)

Correct answers: C-C-C-D-B-B-B-C-C-B

Section 2.4 (Homeostasis in the human body)

Correct answers: A-A-A-C-D

Response to activties

Activity 2.1

The nervous system plays a central role in coordinating rapid responses to environmental changes. This involves various components such as the brain, spinal cord, and peripheral nerves. Additionally, the endocrine system, particularly hormones produced by glands such as the adrenal glands and thyroid gland, also contributes to coordinating responses to environmental stimuli. Together, these systems enable organisms to perceive and react to changes in their surroundings efficiently.

Activity 2.2

The central nervous system (CNS) consists of the brain and spinal cord, which serve as the main processing and control centers of the body. They receive and interpret sensory information, generate responses, and coordinate bodily functions.

On the other hand, the peripheral nervous system (PNS) includes all nerves outside the CNS, connecting it to the rest of the body. It comprises sensory nerves that convey information from sensory organs to the CNS, and motor nerves that transmit signals from the CNS to muscles and glands, enabling movement and physiological responses.

Activity 2.3

Neurons are specialized cells that transmit electrical impulses and communicate with each other, enabling the nervous system to process information and generate responses. They are responsible for tasks such as sensing stimuli, processing information, and sending signals to other neurons, muscles, or glands. On the other hand, glial cells, or neuroglia, provide support and protection to neurons. They perform various functions such as insulating neurons, maintaining the chemical environment around neurons, providing structural support, and helping repair damaged neurons. While neurons are primarily involved in transmitting

signals, glial cells play essential roles in maintaining the health and function of the nervous system.

Activity 2.4

1. Neurons are individual cells that transmit electrical signals within the nervous system, while nerves are bundles of axons (long projections of neurons) that transmit signals between the brain, spinal cord, and other parts of the body.

2. Neurons are not continuous structures like wires. They are individual cells with gaps between them called synapses, where signals are transmitted chemically.

Activity 2.5

1. Synapses are crucial for neurotransmission because they allow neurons to communicate with each other by transmitting chemical signals called neurotransmitters. This enables the transfer of information between neurons and is essential for various functions in the nervous system, including sensory perception, motor control, and cognitive processes.

2. An action potential is a brief electrical signal that travels along the membrane of a neuron. It is generated when the neuron is stimulated, causing a sudden change in membrane potential. This change in voltage triggers the rapid opening and closing of ion channels, leading to the propagation of the action potential along the length of the neuron.

3. An action potential propagates from one neuron to another through a process called synaptic transmission. When an action potential reaches the presynaptic terminal of a neuron, it triggers the release of neurotransmitters into the synaptic cleft. These neurotransmitters bind to receptors on the postsynaptic membrane of the receiving neuron, causing changes in its membrane potential and generating a new action potential if the threshold is reached.

4. An impulse passes from one neuron to another through synaptic transmission. When an action potential reaches the presynaptic terminal of the transmitting neuron, it triggers the release of neurotransmitters into the synaptic cleft. These neurotransmitters then bind to receptors on the postsynaptic membrane of the receiving neuron, initiating changes in its membrane potential and propagating the impulse along the neural circuit.

Activity 2.6

Synapses are specialized junctions between neurons that facilitate communication in the nervous system. When an action potential reaches the presynaptic terminal of a neuron, it triggers the release of neurotransmitters into the synaptic cleft. These neurotransmitters bind to receptors on the postsynaptic membrane of the receiving neuron, causing changes in its

membrane potential. This process allows for the transmission of signals from one neuron to another, enabling the transfer of information throughout the nervous system.

Activity 2.7

1. Neuromuscular junctions are specialized synapses between motor neurons and muscle fibers. They allow for the transmission of signals from motor neurons to muscles, resulting in muscle contraction.

2. Specialized types of synapses include electrical synapses, which allow for direct electrical communication between neurons, and chemical synapses, which involve the release of neurotransmitters to transmit signals between neurons.

3. Neurotransmitters are chemical messengers that transmit signals across synapses. Some common neurotransmitters include acetylcholine, which is involved in muscle contraction and memory formation, dopamine, which regulates movement and emotion, serotonin, which regulates mood and sleep, and glutamate, which is the primary excitatory neurotransmitter in the brain. Each neurotransmitter has specific roles in modulating neural activity and coordinating various functions in the nervous system.

Activity 2.8

The nervous system plays a central role in coordinating and providing rapid responses to changes in the environment. It involves various components such as the brain, spinal cord, and peripheral nerves. These structures receive sensory information from the environment, process it, and generate appropriate responses to maintain homeostasis and ensure survival. Additionally, the endocrine system, through the release of hormones from glands such as the adrenal glands and thyroid gland, also contributes to coordinating responses to environmental stimuli. Together, the nervous and endocrine systems enable organisms to perceive and react to changes in their surroundings efficiently.

Activity 2.9

1. Cranial and spinal nerves: Cranial nerves emerge directly from the brain and are responsible for sensory and motor functions of the head and neck. Examples include the optic nerve (vision) and the facial nerve (facial expression). Spinal nerves arise from the spinal cord and control movements and sensations in the rest of the body.

2. The right and left hemispheres of the brain: The brain's right hemisphere is associated with creativity, intuition, and spatial awareness, while the left hemisphere is linked to logical reasoning, language processing, and analytical thinking. Each hemisphere controls the opposite side of the body, with the left hemisphere controlling the right side and vice versa.

Activity 2.10

1. Reflexes occur rapidly because they involve a simple neural pathway that bypasses the brain, allowing for immediate response to stimuli.

2. All reflexes are not straightforward. While some reflexes are simple and involve only a few neurons, others may be more complex and involve multiple neural pathways.

3. Reflexes contribute to our safety by providing quick, automatic responses to potential threats or dangers in our environment. They also play a role in learning by helping us adapt to new situations and experiences.

4. The main difference between voluntary actions and reflex actions is that voluntary actions are under conscious control and require processing by the brain, while reflex actions occur automatically without conscious thought and involve a rapid response through neural circuits in the spinal cord.

Activity 2.11

1. Ivan Pavlov's experiment on dogs involved classical conditioning, where he paired a neutral stimulus (a bell) with a stimulus that naturally elicited a response (food). Over time, the bell alone elicited a conditioned response (salivation) in the dogs, demonstrating associative learning.

2. Example of a reflex action: Knee-jerk reflex. When the patellar tendon below the kneecap is tapped, it stretches the quadriceps muscle. This stretch is detected by sensory neurons (afferent pathway), which send signals to the spinal cord. In response, motor neurons (efferent pathway) relay signals back to the quadriceps, causing it to contract and extend the leg.

Activity 2.12

1. A drug is a substance that alters the functioning of the body or mind when introduced into the body.

2. a. Drug use refers to the consumption of substances for their intended purpose, such as for medical treatment.

b. Drug abuse involves the excessive or improper use of drugs, leading to negative consequences such as health problems, impaired judgment, or social issues.

c. Drug dependence, or addiction, is a condition characterized by compulsive drug-seeking and use, despite harmful consequences, often accompanied by physical and psychological dependence on the drug.

Activity 2.13

1. Drug addiction refers to a chronic disorder characterized by compulsive drug-seeking behavior and drug use despite harmful consequences.

2. Drug dependence involves the physical and psychological reliance on a drug, often leading to withdrawal symptoms when drug use is discontinued.

3. Withdrawal symptoms are physical and psychological symptoms that occur when a person stops using a drug after a period of dependence. These symptoms vary depending on the drug but may include anxiety, nausea, sweating, and cravings.

Activity 2.14

Some of the most commonly abused drugs or substances used by young people in Ethiopia include:

1. Khat (Catha edulis)
2. Tobacco (cigarettes)
3. Alcohol

Activity 2.15

Harmful chemicals found in cigarettes include nicotine, tar, carbon monoxide, formaldehyde, ammonia, and benzene. Smoking is linked to numerous diseases, including lung cancer, heart disease, stroke, respiratory diseases (such as chronic bronchitis and emphysema), and various cancers (such as throat, mouth, esophageal, bladder, pancreatic, and stomach cancers). Additionally, smoking increases the risk of developing conditions like diabetes, osteoporosis, and infertility.

Activity 2.16

Alcohol can impact the health of young people both directly and indirectly. Direct effects include liver damage, brain impairment, increased risk of accidents, and addiction. Indirect effects may involve poor decision-making leading to risky behaviors, academic or job-related problems, and relationship difficulties.

Activity 2.17

1. The economic significance of khat lies in its role as a major cash crop and source of income for farmers and traders, particularly in regions where it is cultivated. However, its detrimental effects on the economy include decreased productivity, diversion of resources from other crops, and potential social and health costs associated with its consumption.

2. Unprotected sex under the influence of khat can increase the risk of HIV/AIDS infection due to impaired judgment and decision-making. Additionally, khat use may contribute to risky sexual behaviors and practices, such as multiple partners or inconsistent condom use, further elevating the risk of HIV/AIDS transmission.

Activity 2.18

The health impacts of drug abuse on individuals include physical and mental health problems such as addiction, overdose, infectious diseases (like HIV/AIDS and hepatitis), mental disorders, and organ damage. Social consequences may include strained relationships, financial difficulties, legal problems, unemployment, homelessness, and stigma.

For families, drug abuse can lead to emotional distress, breakdown of family dynamics, domestic violence, child neglect or abuse, financial strain, and social isolation. Communities may suffer from increased crime rates, decreased productivity, strained healthcare systems, loss of workforce, and decreased community cohesion.

Activity 2.19

The human skin serves several important functions, including protection against pathogens and physical damage, regulation of body temperature, sensation of touch, synthesis of vitamin D, and excretion of waste products through sweat glands.

Activity 2.20

The basic components of human skin include the epidermis (outer layer), dermis (middle layer), and subcutaneous tissue (innermost layer). The epidermis consists mainly of epithelial cells and provides protection against pathogens and UV radiation. The dermis contains connective tissue, blood vessels, nerve endings, sweat glands, and hair follicles. The subcutaneous tissue is primarily composed of fat cells and provides insulation and padding.

Activity 2.21

1. Human skin color is influenced by various pigments, primarily melanin, which is produced by melanocytes in the epidermis. Other pigments such as carotene and hemoglobin also contribute to skin coloration.

2. Some common skin disorders include acne, eczema, psoriasis, dermatitis, rosacea, hives (urticaria), fungal infections (such as athlete's foot or ringworm), warts, and skin cancer (including melanoma, basal cell carcinoma, and squamous cell carcinoma).

Activity 2.22

Variation in people's responses to the same stimulus can be attributed to factors such as genetic differences, individual experiences, psychological factors, and differences in sensory perception. Additionally, environmental factors and context can also influence how individuals interpret and respond to stimuli.

Activity 2.23

One's ability to taste foods is diminished when they have a common cold due to inflammation and congestion in the nasal passages, which affects the sense of smell. Since taste is closely linked to smell, a reduced ability to smell leads to a diminished perception of flavors.

Activity 2.24

To conduct the activity:

1. Begin by observing the size of your own pupils in a setting with normal working light.
2. Cover your eyes with your hands or a piece of cloth for approximately one minute, ensuring your eyes remain open.
3. After removing the cover, observe your pupils closely. Take note of any immediate changes in pupil size and continue observing as your eyes adjust to normal light levels.
4. Increase the light intensity by moving outside into sunlight or closer to windows. Once again, observe your pupils and record any changes in response to the brighter light. Describe your observations thoroughly.

Activity 2.25

1. The retina is a layer of tissue at the back of the eye that contains photoreceptor cells called rods and cones. Its function is to receive light and convert it into neural signals that are sent to the brain for visual processing.
2. Color blindness, also known as color vision deficiency, is a condition where individuals have difficulty distinguishing between certain colors, particularly red and green or blue and yellow. This is often caused by abnormalities or deficiencies in the cone cells of the retina responsible for color vision.

Activity 2.26

Different types of human eye defects include myopia (nearsightedness), hyperopia (farsightedness), astigmatism, and presbyopia (age-related decline in near vision). Solutions for addressing these defects include corrective lenses (glasses or contact lenses), refractive surgery (such as LASIK), and in some cases, orthokeratology or implantable lenses.

Activity 2.27

The primary functions of the human ear include detecting sound waves, maintaining balance and equilibrium, and transmitting auditory signals to the brain for interpretation.

Activity 2.28

Potential causes of deafness or hearing loss include genetics, aging, noise exposure, ototoxic medications, infections, trauma, ear malformations, tumors, autoimmune diseases, and conditions like Meniere's disease.

Activity 2.29

The endocrine system communicates through the secretion of hormones into the bloodstream, which then travel to target cells or organs to regulate various bodily functions. Differentiating between exocrine and endocrine glands:

- Exocrine glands secrete their products into ducts that carry them to body surfaces or cavities, such as sweat glands or salivary glands.
- Endocrine glands secrete hormones directly into the bloodstream, which then travel to target cells or organs to regulate physiological processes. Examples include the thyroid gland and adrenal glands.

Activity 2.30

The anterior pituitary gland produces hormones such as growth hormone (GH), adrenocorticotropic hormone (ACTH), thyroid-stimulating hormone (TSH), follicle-stimulating hormone (FSH), luteinizing hormone (LH), and prolactin (PRL). Problems associated with these hormones include dwarfism (GH deficiency), gigantism or acromegaly (GH excess), adrenal insufficiency (ACTH deficiency), thyroid disorders (TSH imbalance), infertility (FSH or LH deficiency), and abnormal lactation (PRL excess).

The posterior pituitary gland releases hormones such as oxytocin and antidiuretic hormone (ADH). Problems associated with these hormones include diabetes insipidus (ADH deficiency) and uterine dysfunction or breastfeeding difficulties (oxytocin imbalance).

Activity 2.31

1. Thyroxine regulates metabolism, growth, and development in the body.
2. The current situation of goiter cases in Ethiopia is still prevalent due to iodine deficiency, although efforts have been made to reduce its occurrence through iodized salt programs.
3. Women and children are more affected by iodine deficiency than men because they have higher iodine requirements, especially during pregnancy and childhood, for proper thyroid hormone synthesis and fetal development.

Activity 2.32

The Zona glomerulosa secretes mineralocorticoids, mainly aldosterone, which regulates electrolyte balance and blood pressure. Hypersecretion can lead to hypertension; hyposecretion can result in electrolyte imbalances.

The Zona fasciculata secretes glucocorticoids, primarily cortisol, which regulate metabolism, immune function, and stress response. Hypersecretion can cause Cushing's syndrome; hyposecretion can lead to Addison's disease.

The Zona reticularis secretes androgens, such as dehydroepiandrosterone (DHEA), which contribute to the development of secondary sexual characteristics. Hypersecretion can result in virilization, hyposecretion may lead to reduced libido and muscle mass.

Activity 2.33

Type I diabetes is an autoimmune condition where the body's immune system attacks and destroys insulin-producing beta cells in the pancreas. It typically occurs in childhood or adolescence and requires insulin therapy for management. Type II diabetes, on the other hand, is characterized by insulin resistance, where the body's cells become less responsive to insulin. It often develops in adults and is associated with obesity and lifestyle factors.

Activity 2.34

The development of secondary sexual characteristics in boys and girls is primarily influenced by hormonal changes during puberty. In boys, testosterone levels increase, leading to the growth of facial and body hair, deepening of the voice, and muscle development. In girls, estrogen levels rise, resulting in breast development, widening of hips, and the onset of menstruation.

Activity 2.35

The hormones that influence the female reproductive system include estrogen, progesterone, follicle-stimulating hormone (FSH), luteinizing hormone (LH), and gonadotropin-releasing hormone (GnRH).

During the menstrual cycle, FSH stimulates the growth and maturation of ovarian follicles, which produce estrogen. Rising estrogen levels trigger the thickening of the uterine lining.

LH surge triggers ovulation, the release of a mature egg from the ovary. After ovulation, the ruptured follicle transforms into the corpus luteum, which produces progesterone.

Progesterone helps maintain the uterine lining in preparation for implantation of a fertilized egg. If fertilization does not occur, progesterone levels decline, leading to menstruation and the start of a new cycle. These hormones play crucial roles in regulating the menstrual cycle and fertility.

Activity 2.36

The kidneys regulate the levels of water and ions in the human body through processes such as filtration, reabsorption, and secretion. They filter waste products and excess substances from the blood, reabsorb essential ions and water, and excrete excess ions and waste products in urine, thereby maintaining the body's fluid and electrolyte balance.

Activity 2.37

The human body regulates temperature through various physiological and behavioral methods. Physiological methods include sweating, vasodilation, and shivering, while behavioral methods encompass seeking shade, changing clothing, and adjusting activity levels to maintain homeostasis.

Activity 2.38

Traditional methods used to regulate body homeostasis may include herbal remedies, dietary practices, breathing techniques, and cultural rituals aimed at maintaining balance and well-being.

Activity 2.39

Chemical regulation in the human body involves various processes such as hormone secretion, neurotransmitter release, enzyme activity regulation, and pH balance maintenance. These processes are essential for coordinating bodily functions, maintaining homeostasis, and responding to internal and external stimuli.

UNIT THREE: CLIMATE CHANGE

Table of Contents

Unit overview

Dear learner, welcome to the third unit of the second module. In this unit you will learn about climate change. You will also learn the basc causes of climate change, the effects of climate change on biodiversity, agricultural productivity and human being. You will study about natural disasters caused as a result of climate change and some of the exercises or precautions needed during natural disaster. You will also learn about some of the international conventions regarding climate change and the implementation status of international conventions with pertinent examples. Moreover, you will also discuss some of the measures our country Ethiopia has taken to combat climate change.

Dear learner, at the end of this unit, you 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
- Analyze implementation practice of international conventions to mitigate climate change.

Unit study time (11 hrs)

Dear leraner, the required time to accomplis unit three is 11 hrs. You should use the allocated time properly to cover the contents of the third unit.

Section 3.1 Climate Change: Causes and Effects

3.1.1 Definition of Climate Change

What is climate change?

Dear learner, Climate change refers to the worldwide occurrence of alterations in the Earth's climate system, including variations in temperature, precipitation, and wind patterns. These changes are primarily attributed to human activities. Climate change is a gradual and persistent shift in the atmospheric conditions that persists over several decades or even longer periods of time.

3.1.2 Causes of climate change

What causes climate change?

Dear reader, it is important to acknowledge that climate change is primarily driven by both **natural** and **human-induced** (**anthropogenic**) factors that affect the Earth's energy budget. Human activities such as the combustion of fossil fuels, deforestation, and livestock farming have significantly contributed to the alteration of the Earth's climate and temperature. This has resulted in a substantial increase in the concentration of atmospheric CO2, with more than a 40% rise since 1970. Consequently, the excessive release of greenhouse gases into the atmosphere intensifies the greenhouse effect, leading to global warming. Fundamentally, climate change occurs due to a disruption in the Earth's energy

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.

Activity 3.1

Dear learner, do you believe weather, climate, climate variability, and climate change are distinct concepts? If so, could you explain their differences?

balance, which is associated with the reduction of solar energy reflected back into space. As a consequence, the Earth accumulates more energy, exacerbating the effects of climate change.

What are greenhouse gases?

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 so that it keeps the earth’s temperature at an average 14˚C (57˚F). The gases act like glass walls of a greenhouse and ence 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.

Greenhouse effect

Greenhouse gases are released into the atmosphere at various scopes (See Figure 3.1) that have an influence on the earth's energy balance by trapping heat in the atmosphere, which makes the Earth warmer. In Earth’s atmosphere such as carbon dioxide, methane, nitrous oxide and Hydrofluorocarbons (HFCs) act as a **greenhouse**, preventing a certain amount of heat radiation from escaping back to space.

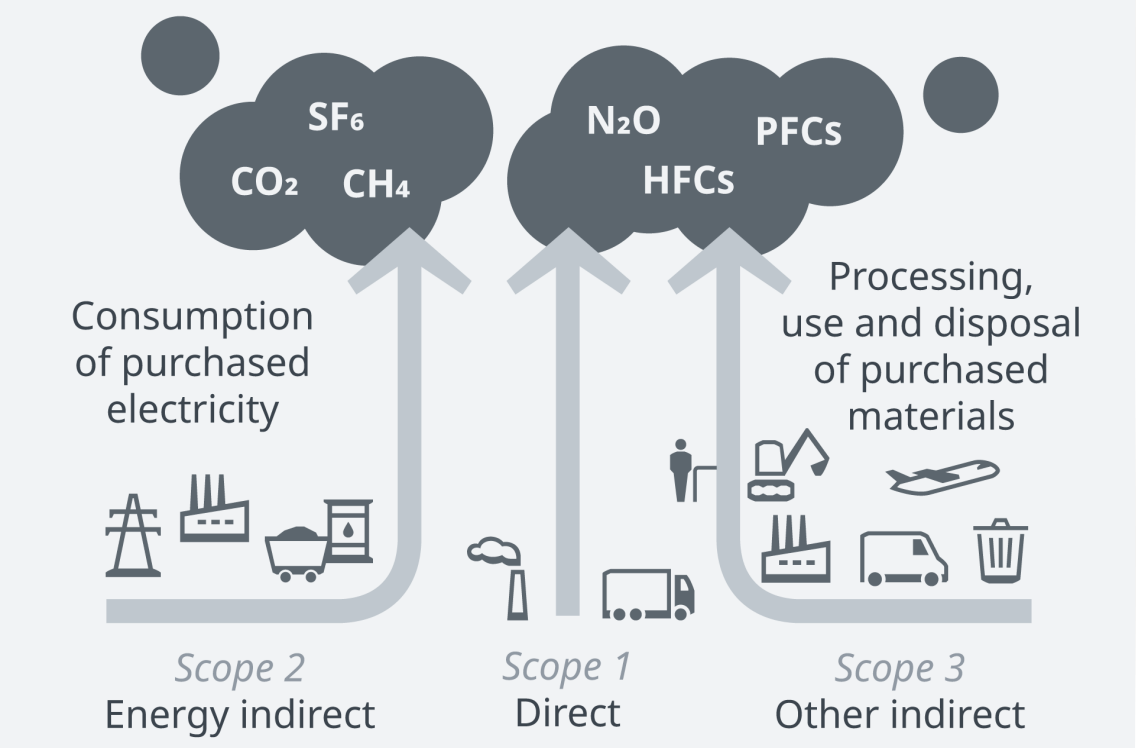


Figure 3.1. Source–Path relationship of Greenhouse gases

Since the Industrial Revolution, human activities have added very large quantities of greenhouse gases into the 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 3.1. 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) has been the GHG responsible for the greatest amount of warmingto 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 (See Table 3.1).

Activity 3.2

Dear learner,

- How would you define global warming and climate change?
- Do you consider the sun a significant contributor to recent climate changes?
- What is the fate of carbon dioxide after its emission into the atmosphere?
- Is climate variability a consistent feature throughout history?

Carbon dioxide absorbs and radiates heat warmed by sunlight, and thermal infrared energy (heat). Unlike oxygen or nitrogen 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 has caused the earth's temperature to rise (See Figure 3.2 and Figure 3.3).

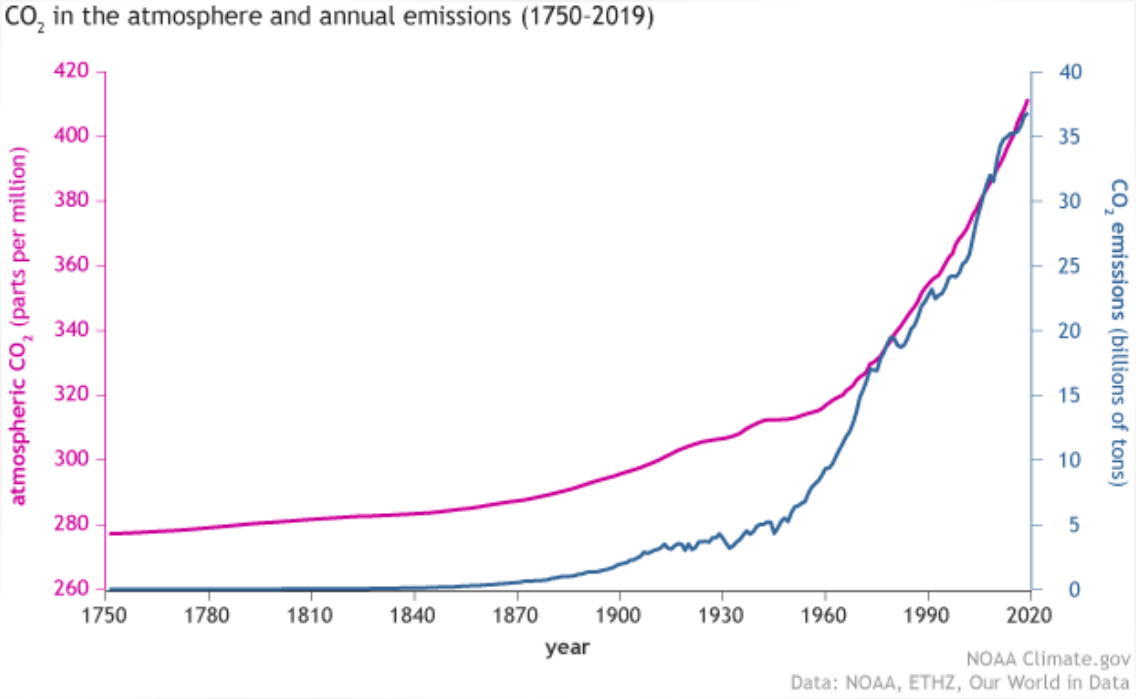


Figure 3.2. Progressive increase of of atmospheric Carbon dioxide concentrations since 1750 GC.

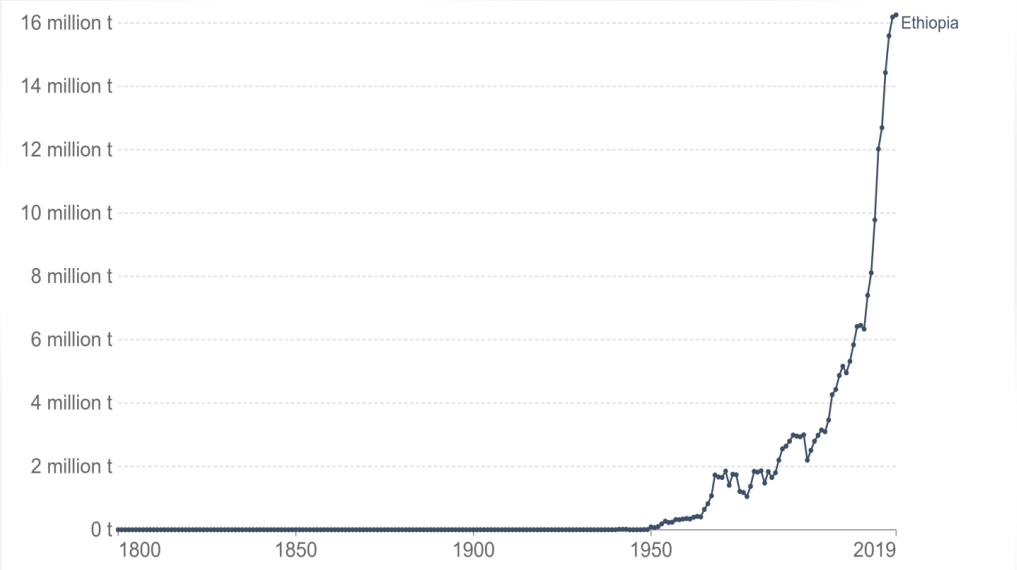


Figure 3.3. Ethiopia's annual CO_2 emission

Activity 3.3

Dear learner, could you explore various sources, including books and the internet, to learn about greenhouse gases, their sources of emission, and their effects on the environment?

In nature, CO_2 is exchanged continually among 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% is emitted from fossil fuel combustion and 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 have been adding CO2 to the atmosphere. As a result, a substantial fraction of the CO2 that has been emitted from human activities has accumulated 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, the current concentrations are substantially higher than they have been in at least 800,000 years.

3.1.3 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.

Activity 3.4

Dear learner, could you describe some of the consequences of climate change?

Figure 3.4 Greta Thunberg, Climate activist and Founder of Climate School Strike

Climate change destabilizes the equilibrium of the earth's temperature and has far-reaching effects on human beings and the environment (See Figure 3.5). Throughout the history of global warming, the energy balance and thus the temperature change of the earth has been posing a significant impact on humans and the environment. Accordingly, 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

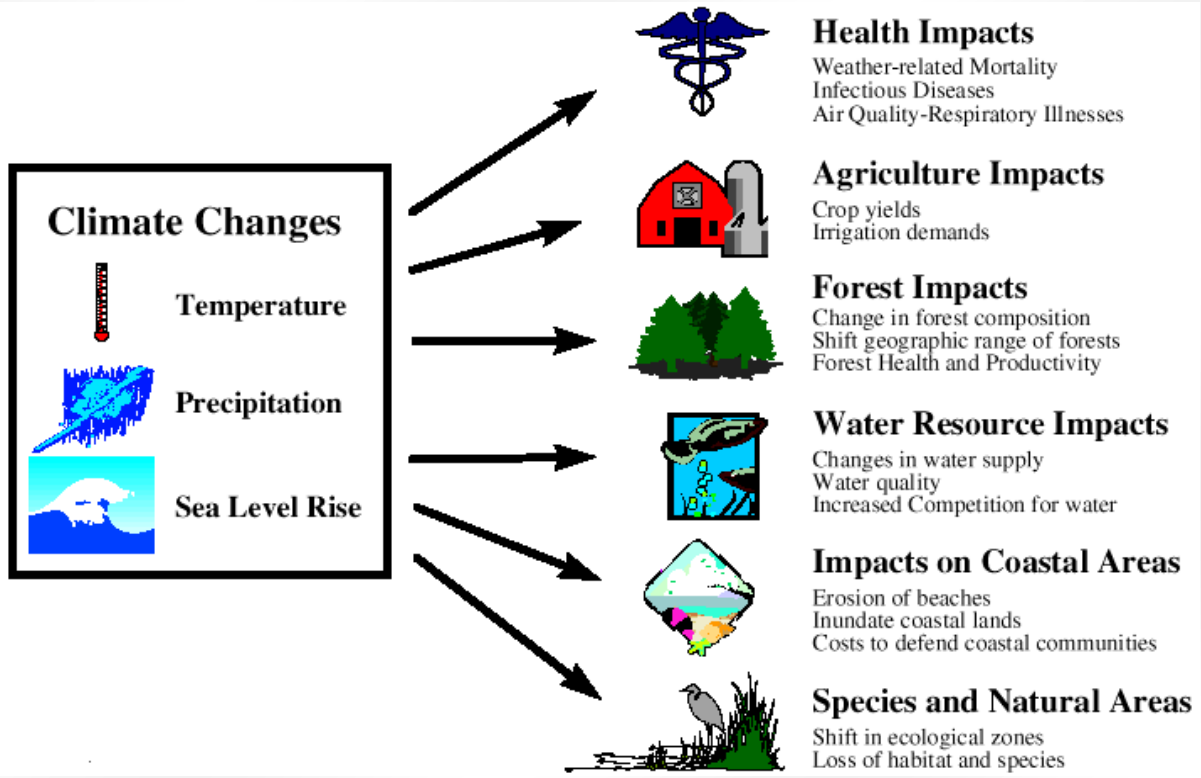


Figure 3.5. Potential climate change impacts

3.1.3.1 Effects of climate change on biodiversity

How do you describe the effects of climate change on biodiversity?

Derived from biological resources, biodiversity provides immense direct benefits to humans with at least 40% of the world's economy. Maintaining biodiversity provides greater food security, opportunities for economic development, and provides a foundation for new pharmaceuticals and other medical advances. On the other hand, however, climate change is affecting the habitats (See Figure 3.6) 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 the 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 3.6 Changes in rainfall patterns can damage land, plants and animals

3.1.3.2 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 (See Figure 3.5)

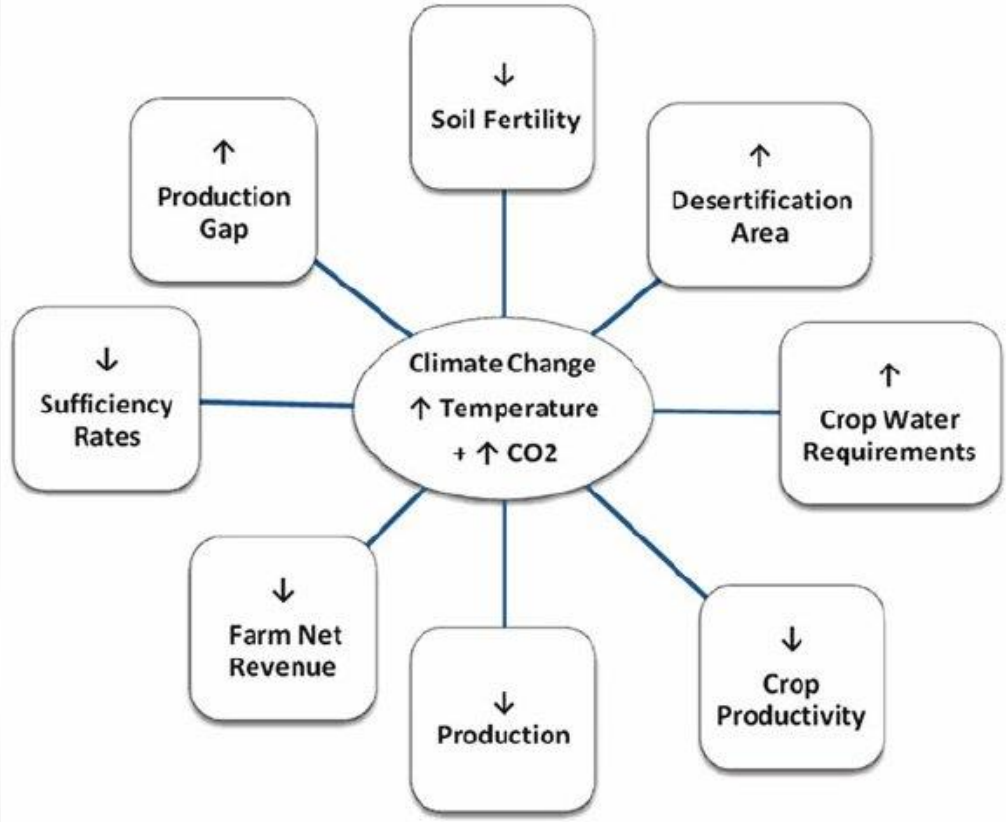


Figure 3.7 Climate change and its potential impacts on agriculture.

3.1.3.3 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 (See Figure 3.8).

Figure 3. 8 Galema forest on fire, Chilalo, Oromia state Ethiopia

Section 3.2 Climate change and natural disasters

Climate hazards are natural events in weather cycles. In our planet, we always have had hurricanes, droughts and wildfires, high winds and flooding (See Figures 3.9 - 3.11). 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 occur. As more water vapor is evaporated into the atmosphere, it becomes fuel for more powerful storms to develop.

Activity 3.5

Dear learner, could you describe the causes and effects of natural disasters such as floods, landslides, and ice melts, as well as the safety rules and precautions to take during these events?

Figure 3.9. Heavy rains and storms caused damage and flooding to the Lietchuor camp in Ethiopia, Gambella region.

Figure 3.10 Dust storms in Eastern Ethiopia

i. 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 land areas.

ii. 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 (See Figure 3.11).

Figure 3.11 Failed crops as a result of climate change, Ethiopia

iii. 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 that involves the identification of threats through implementation of the proposed mitigation measures (See Figure 3.10). 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 that must be be takenand followed to save precious lives.

Figure 3.12. Elements of Comprehensive risk management

Here under are a few precautions to be taken during natural disasters.

iv. Earthquakes

- The shifting of tectonic plates under the earth's crust which are responsible for mass destruction causes earthquakes. When faced with an earthquake, these tips can be of use:

  If you are indoors

- Take cover under a strong 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 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.

v. 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.

vi. 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.

vii. 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

Section 3.3 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 (See Figure 3.13).

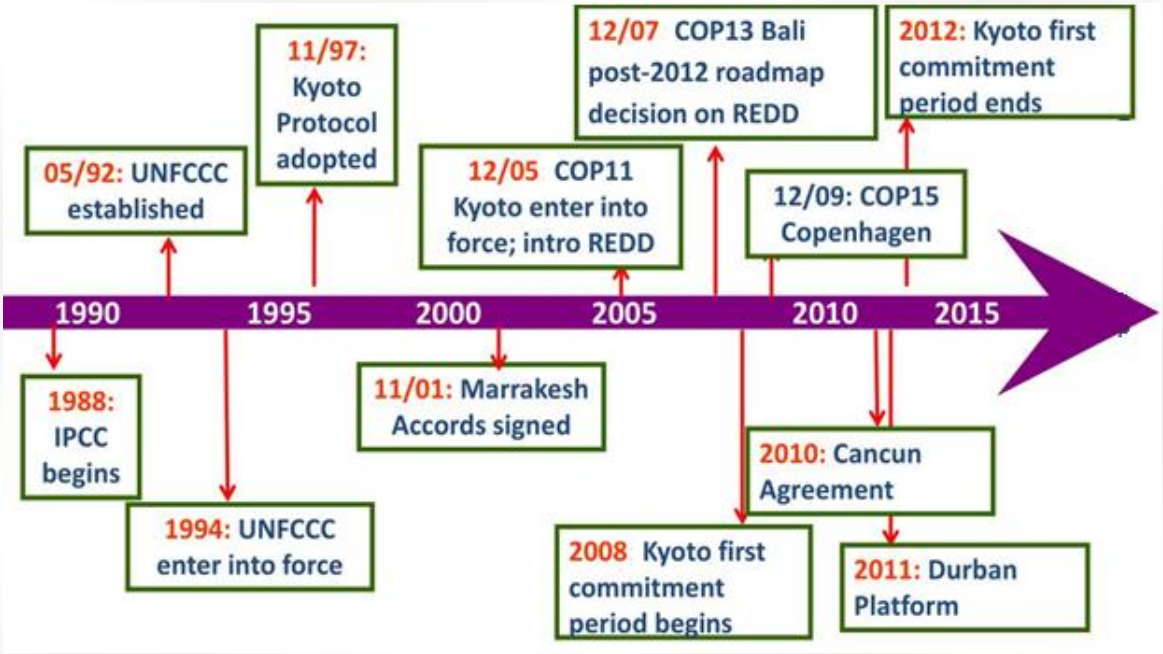


Figure 3.13. Climate Policy Timeline

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. The Copenhagen agreement was aimed " at strengthening the global response to the threat of climate change, in the context of sustainable development and efforts to eradicate poverty" and the agrrement 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.

3.3.1 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 member countries of the United Nations are among the 197 Parties of the Convention.

3.3.2 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, such as 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 (See Figure 3.13). 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 the agreement had been reached in 1997. “It reflects a commitment from our generation to act in the interests of future generations,” he said.

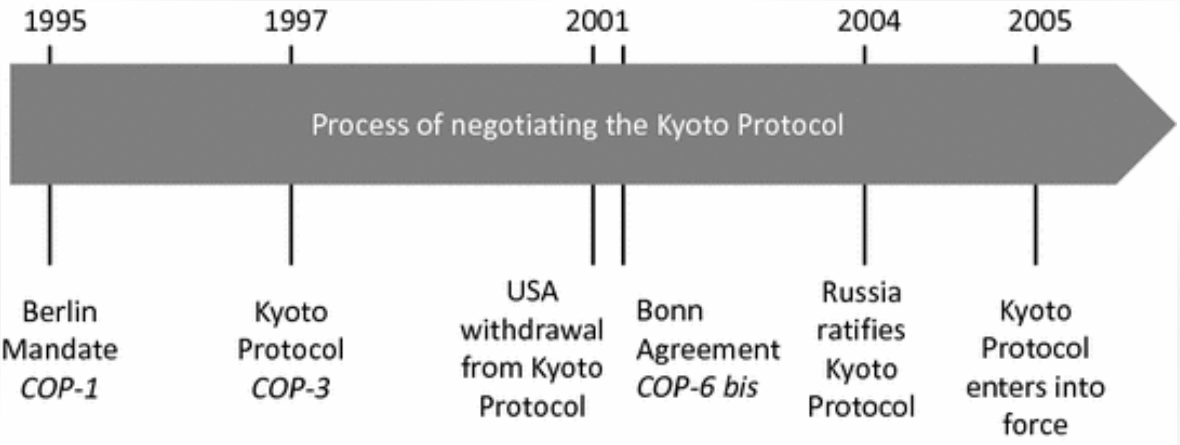


Figure 3.14. The Negotiation process leading to the Kyoto Protocol

3.3.3 International and national practices of Implementation of conventions

Ethiopia Green Legacy Initiave

Ethiopia is one of the most drought-prone countries in the world. 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 have exacerbated 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. The initiative 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 the 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 the 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 a considerable potential for fishing and irrigation development.

Activity 3.6

Dear learner,

1. Could you discuss the contribution of the Ethiopian Green Legacy Initiative campaign, launched in 2019, in terms of implementing international protocols? Additionally, could you elaborate on concepts such as carbon sequestration, carbon trading, and their connection to the Green Legacy Initiative?
2. Can you explain how the Grand Ethiopian Renaissance Dam (GERD) contributes to supporting the green economy and mitigating the adverse effects of climate change?

Section 3.4 Unit summary

❁ Dear learner, 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 largely caused by human activities.
- Natural and anthropogenic substances are the main causes of climate change. Human activities have been 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 (CO2)..
- Greenhouse gases (GHGs) such as water vapour, Carbon dioxide (CO2), 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.

Assignment questions

Give answer for the following questions

1. What is climate change? Explain how it is different 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?

Unit 3

Activity 3.1

Weather, climate, climate variability, and climate change are distinct concepts.

Weather refers to the short-term atmospheric conditions in a specific location at a given time, such as temperature, humidity, precipitation, and wind.

Climate, on the other hand, describes the long-term average of weather patterns in a particular region over a period of time, typically 30 years or more.

Climate variability refers to the natural fluctuations and variations in climate patterns over shorter time scales, ranging from months to decades.

Climate change refers to the long-term alterations in Earth's climate patterns, often attributed to human activities such as burning fossil fuels, deforestation, and industrial processes, leading to shifts in temperature, precipitation patterns, and sea levels over decades to centuries.

Activity 3.2

- Global warming refers to the long-term increase in Earth's average surface temperature due to human activities, primarily the release of greenhouse gases.
- The sun is not a significant contributor to recent climate changes; rather, human activities, such as burning fossil fuels and deforestation, are the main drivers of current climate change.
- After emission into the atmosphere, carbon dioxide can remain for hundreds to thousands of years, contributing to the greenhouse effect and trapping heat in the atmosphere.
- Climate variability has been a consistent feature throughout Earth's history, driven by natural factors such as volcanic eruptions, solar radiation, and changes in Earth's orbit.

Activity 3.3

Greenhouse gases are gases in the Earth's atmosphere that trap heat, leading to the greenhouse effect. Major greenhouse gases include carbon dioxide (CO2), methane (CH4), nitrous oxide (N2O), and fluorinated gases. They are emitted primarily through human activities such as burning fossil fuels, deforestation, agriculture, and industrial processes. The effects of greenhouse gases include global warming, climate change, rising sea levels, altered weather patterns, and disruptions to ecosystems and biodiversity.

Activity 3.4

Some consequences of climate change include rising global temperatures, melting polar ice caps and glaciers, sea-level rise, extreme weather events such as hurricanes and heatwaves, changes in precipitation patterns leading to droughts and floods, disruptions to ecosystems and biodiversity, and impacts on agriculture, water resources, and human health.

Activity 3.5

Natural disasters such as floods, landslides, and ice melts are often caused by various factors such as heavy rainfall, snowmelt, or rapid thawing. The effects can include property damage, loss of life, displacement of communities, and ecological disruptions. Safety rules and precautions during these events include staying informed about weather forecasts, avoiding

flood-prone areas, evacuating if necessary, seeking higher ground during floods, and avoiding steep slopes during landslides.

Activity 3.6

1. Ethiopian Green Legacy Initiative: The Green Legacy Initiative, initiated in 2019, significantly contributes to aligning with international protocols by focusing on reforestation and afforestation efforts. It aims to combat deforestation and mitigate climate change impacts. Carbon sequestration, a key concept in this initiative, involves capturing and storing carbon dioxide from the atmosphere by planting trees and restoring degraded ecosystems. Furthermore, the initiative's efforts are connected to carbon trading through potential carbon offset programs, where the carbon sequestered by tree planting could be traded as carbon credits to support climate change mitigation efforts globally.

2. Grand Ethiopian Renaissance Dam (GERD): The GERD plays a vital role in supporting Ethiopia's green economy and addressing climate change challenges. By harnessing renewable hydropower energy, the dam reduces dependence on fossil fuels and mitigates greenhouse gas emissions, aligning with sustainable development goals. Furthermore, GERD's reservoir offers opportunities for irrigation, water resource management, and flood control, thereby enhancing resilience to climate change impacts such as droughts and floods. Overall, GERD contributes to Ethiopia's sustainable development and climate change adaptation strategies.