BIOLOGY

Distance Education Module
Grade 12

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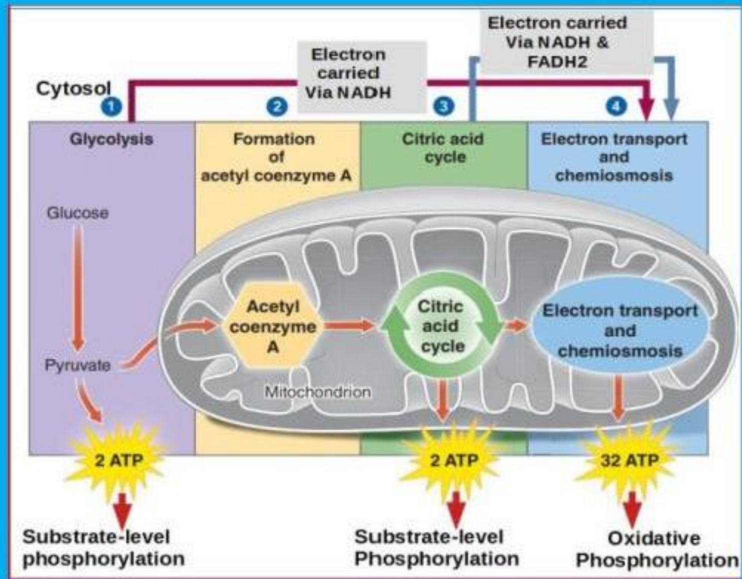

FEDERAL DEMOCRATIC REPUBLIC OF ETHIOPIA
MINISTRY OF EDUCATION

Biology

DISTANCE EDUCATION MODULE

GRADE 12

Module One

THE APPLICATIONS OF BIOLOGY IN DAY-TO-DAY LIVES, MICROBIOLOY, AND ENERGY TRANSFORMATION

Federal Democratic Republic of Ethiopia Ministry of Education

Module One

Distance Material development Team

Writers:

Anbessa Dabassa (PhD.)

Eba Alemayehu (PhD.)

Editors

Meskerem Cheru (MA.) - Curriculum Editor

Yenus Nurei (PhD.) – Language Editor

Designer

Ali Seid (PhD.)

Evaluators

Berhanu Tesfaye (MA, MEd.)

Gebrehana Zeleke (MSc.)

Samuel Desalegn (MSc.)

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Contents

MODULE ONE INTRODUCTION

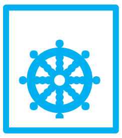
This is the first module of grade 12 Biology for one semester. It designed as distance material for adult learners. The module consists of three units, namely the applications of biology in day-to-day lives, microbiology, & energy transformation. Each unit organized into sections that include Introduction, Minimum Learning Competencies, and sub topics followed by checklist and self – test exercises. At the end of each unit, there are unit summary and a feed – back to the unit summary questions. Moreover, you can find the answers to the self-tests under all the sections at the end page of this module. We hope you enjoyed the learning experience and gained valuable there are references, largely available as free book pdf on the internet, for each unit of the module for further reading.

Even though there are different specific learning strategies / learning methods for the different sections, the following general learning strategies suggested, but not limited, for the adult learner 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

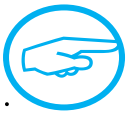
In this module, you will find the following icons or graphic symbols with the description they represent throughout the module.

Lists of symbols used in this module



This tells you there is an overview of the unit and what the unit is about

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

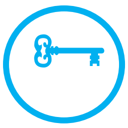


This tells you to take not of or to remember an important point.

This tells you there is a self-test for you to do

This tells you there is a checklist.

This tells you there is a written assignment



This tells you that this is the key to the answers for the self-tests.

Dear distance learner, if you encounter difficulty in understanding some topics in the module, does 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 repeatedly 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 do not 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 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.

MODULE OBJECTIVE

Dear learner, this module consists of three units, each with specific learning outcomes. By completing this module, you will be able to:

- Explain the application of biological knowledge in different areas of their environment
- Discuss the role of biology in enhancing their livelihood
- State the characteristics of microorganisms
- Describe the prevention and treatment mechanisms of diseases caused by microorganisms
- Summarize the process of photosynthesis using a chemical equation.
- Analyze the absorption spectra of chlorophyll a and chlorophyll b using a graph.
- Discuss the mechanism as to how CO_2 is fixed in C3, C4 plants, and CAM Plants.
- Justify the reason why the rate of photorespiration is less in C4 plants as compared to C3 plants.
- Demonstrate whether or not organic molecules (such as starch) are present in leaves.
- Discuss how energy is harvested during aerobic respiration.
- Differentiate between substrate-level phosphorylation and oxidative phosphorylation
- Show the mechanism electron transport system in mitochondria.
- Discuss the significance of fermentation by microorganisms in our daily life.

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 for submission" 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 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.

Unit 1

THE APPLICATIONS OF BIOLOGY IN DAY-TO-DAY LIVES

Overview

☸ **Dear learner**, biology is an interesting branch of science that has been the center of attention for centuries. This complex concept has vexed everyone since ancient times. The fields of science and technology have advanced; yet, many biological phenomena have still demanded a basic explanation. The mystery of the origin of life on earth and the appearance of human beings has remained unsolved. Biology enables us to understand our existence and everything we do in one way or another. It improves our understanding about our body cells that work for us even when we are doing nothing or sleeping. In short, biology plays its part from the moment we are born; grow into a child, experience adolescence, welcome adulthood and then you begin to get older. All these beautiful and fascinating processes seem to be hidden biological laws. In this lesson, however, you will explore some everyday life examples where biology plays an important role in improving agriculture, food and drinks, health and medicine, biofuels, environment and ecosystems, and genetic engineering, etc.

Unit learning outcomes

Dear learner, after the successful completion this unit, you will be able to:

- Explain the application of biological knowledge in different areas in your environment
- Discuss the role of biology in enhancing your livelihood
- Value the contribution of biologists and promises biology will have for the society.

Table of contents

Unit one study time (11 hrs.)

LEARNING STRATEGIES

Dear learner, the following learning techniques can be applied to the main topics or subtopics of this course to enhance your distance learning process. These techniques include mentally practicing, taking brief on-site trips, comparing and contrasting, sketching and photographing actual processes and products, making comparisons, summarizing (outlining and creating flow charts), taking brief notes, and underlining or highlighting important aspects.

SECTION1.1. CONSERVATION OF NATURAL RESOURCES

INTRODUCTION

☸ **Dear learner**, in this section, you will explore the concept of natural resource conservation, which is the protection and management of natural resources for the benefit of current and future generations. You will also learn about the many kinds of natural resources in Ethiopia and how can the people preserve them via a variety of actions and laws.

MINIMUM LEARNING COMPETENCIES

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

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

Dear learner, have you ever studied the conservation of natural resources in your previous courses? **Natural resources** are physical supplies that exist in nature. These include oil, water, air, plants, animals, and energy. In order to prevent natural resources from disappearing, they must be carefully maintained and used.

? List some of the natural resources available in Ethiopia?

Dear learner, Ethiopia has many natural resources, such as, gold, platinum, potash, limestone, natural gas, coal, in addition to lakes, volcanic ocean, and waterfalls (see **Figure 1.1**),and timber, many varieties of crop plants, coffee plantations, species of animals and plants, and many different birds, make up rich ecosystems (see **Figure 1.2**).

? What are the two types of natural resources? Can you give an example for each of them?

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

Key Words

Natural resources: actual and potential resources supplied by nature

Renewable: capable of being produced indefinitely, not used up

Non-renewable: once used, cannot be easily made or replaced

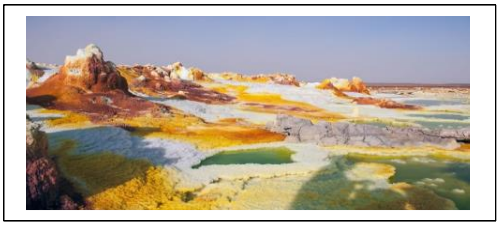
Extinct: no longer in existence

Conservation: the act of preserving, guarding or protecting resources

☞ **Conservation biology** is a mission-oriented science that focuses on how to protect and restore biodiversity, or the diversity of life on Earth.

Dear learner, Conservation is the responsible management and utilization of natural resources to prevent their depletion. For instance, forests can be sustained for thousands of years by properly managing trees, which have the ability to reproduce. However, if all the trees are cut down at once for timber, the forest will not have the chance to regenerate, leading to the loss of all the species dependent on it. Similarly, when an animal is hunted to the point of extinction or its habitat is destroyed, it can no longer find food or reproduce. This results in the permanent loss of other natural resources when a species becomes extinct. The loss can occur within a specific area or on a global scale when species are threatened with extinction.

Hawassa Lake



Volcanoes with sulfur deposits in Ethiopia (Ertale)

Tis Abay water fall

Figure1.1. Natural landscapes in Ethiopia

Dear learner, do you know why natural resources are conserved? As a result of the increasing awareness of the importance of preserving our natural resources, individuals have taken action to promote conservation efforts both locally in Ethiopia and globally. Conservation entails safeguarding and maintaining the natural environment to ensure that non-renewable resources are utilized prudently while renewable resources are effectively managed to avoid depletion in the future. Failure to do so may result in their depletion within a short time frame.

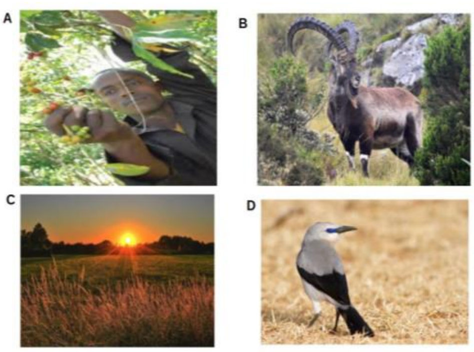


Figure1.2. Some important renewable resources in Ethiopia: Coffee (**a**), Walia Ibex (*Capra walie*) (**b**), Sunlight as a source of energy (**c**), Ethiopian Bush crow (*Zavattariornis stresemanni*) (**d**).

Activity:1.1

1. Please write a report on the main causes and effects of natural resource degradation in Ethiopia. Additionally, discuss some of the strategies and policies that have been implemented to address this issue?

Self-test

Match the following terms with their definitions.

S.no	**A)** Renewable resource, **B)** Non-renewable resource, **C)** Conservation, & **D)** Sustainable development	
1	The practice of caring for natural resources so that they can be used by present and future generations.	
2	A resource that can be replenished naturally or by human intervention within a reasonable period.	
3	A resource that cannot be replenished within a human lifespan or at all.	
4	The use of natural resources in a way that meets the needs of the present without compromising the ability of future generations to meet their own needs.	

Section review question

1. What is the main goal of the National Conservation Strategy of Ethiopia, and what are its four guiding principles?
2. How does the Biodiversity and Forestry Programme of Ethiopia contribute to the conservation and sustainable use of natural resources, and what are some of its key achievements?

✓ **Self-evaluation check list**

Put a tick (√) against each of the following tasks, which you can perform. If you cannot perform any of these tasks, go back and read the lesson for that particular task.

I Can:

S.no	**Questions**	✓ **Check**
1	Define natural resources.	
2	Identify renewable and non-renewable resources.	
3	Classify natural resources as renewable and non-renewable.	

SECTION 1.2. FOOD AND NUTRITIONAL SECURITY

INTRODUCTION

❁ **Dear learner,** in your previous lessons, you have gained knowledge about conserving natural resources and the various types of natural resources available in Ethiopia, along with their definitions. Now, it is time to delve into the concept of food security and insecurity. This important topic has a direct impact on millions of people worldwide. In this section, we will learn about how the United Nations defines and measures these concepts, as well as the root causes of food insecurity in various regions and its effects.

MINIMUM LEARNING COMPETENCIES

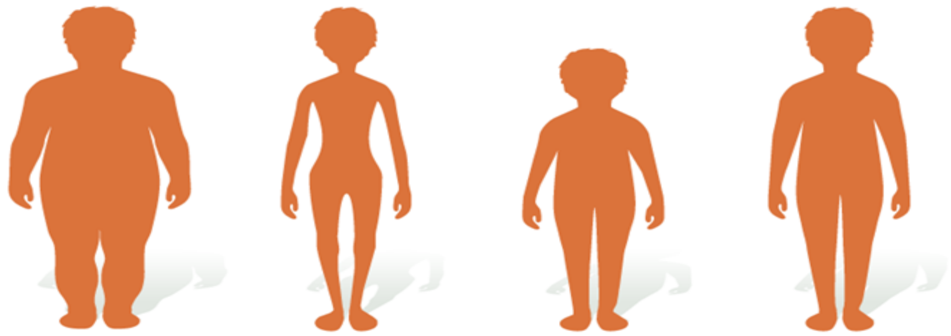
In this section, you will be able to:

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

Dear learner, can you explain food security and insecurity? Food security means that everyone can always access enough food that is healthy, safe, and suitable for their needs and preferences, as stated by the United Nations Committee on World Food Security. This ensures that individuals can maintain a well-balanced diet and lead a healthy and active life-style.

Explain the difference between food security and insecurity?

On the contrary, food insecurity is often associated with poverty and can have long-term consequences on individuals, communities, and a country's potential for development and prosperity. When people face extended periods of inadequate food, they may experience issues such as stunted growth, impaired cognitive function, and increased vulnerability to illnesses (**refer to Figure 1.3**).



Over nutrition: too fat for height and age

Wasting: too thin for height

Stunting: too short for age

Good nutrition status, or may suffer **micronutrient deficiencies**

.

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

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

Nutrition security: Having access to foods and beverages that are healthy, safe, and affordable and meet the dietary needs and preferences of people for a good quality of life.

Dear learner, have you ever heard of nutritional security before? **Nutritional security** is the ability of individuals to access sufficient, safe, and nutritious foods, as well as safe water and proper sanitation. It also includes access to healthcare services and knowledge of sound household and community practices in childcare, food storage and preparation, and hygiene.

Which biological application is important for maintaining food security?

Dear learner, food security is achieved when there is enough food available for everyone when people have the means to purchase high-quality food, and when there are no barriers preventing access to food. Biologists play a crucial role in producing high-nutrient staple crops and developing new products that can combat malnutrition and improve food utilization. Biotechnologists are responsible for designing the manufacturing processes and machinery used in food and drink production. Through these innovations, biologists work towards ensuring food security within countries and across the world. These efforts allow for the production of products with consistent flavor, color, and texture in large quantities.

Self-Test:

Provide the correct answer by choosing either True or False. If necessary, provide a detailed description.

1. Food insecurity is not related to poverty and has no lasting impacts on people, communities, and countries.
2. Nutrition security is a situation where individuals have access to sufficient, safe and nutritious foods, safe water and adequate sanitation, health care services, and knowledge of sound household and community practices.
3. Food security is ensured only if enough food is available for all in a country.

4. Biologists work to ensure food security within a country, and across the world, through producing high-nutrient staple crops and developing new products that can combat malnutrition.
5. The use of microbial fermentation in food processing is a biological application that helps maintain food security.

Activity: 1.2

The activity question is important to strengthen your understanding. So, briefly describe the following activity questions. Write a short answer for the following question(s). You may use the internet, as well as digital and print educational resources as references.

1. What are the various elements that influence the availability of food?
2. How does food security differ from nutritional security?
3. What are the consequences of lacking food and nutritional security?
4. Identify a biological process that is crucial for upholding food security.

Section review question

1. What is a primary cause of food insecurity?

   A) Overnutrition

   B) Adequate sanitation

   C) Poverty and unequal access to resources

   D) Excess food waste

2. Sustainable agricultural practices contribute to food security by:

   A) Increasing dependency on chemical fertilizers.

   B) Promoting biodiversity.

   C) Encouraging monoculture.

   D) Reducing crop yields.

3. What are some of the factors that affect nutrition security?

   a) Availability of food b) Affordability of food c) Dietary needs and preferences d) All of the above

4. Which of the following is a consequence of nutritional insecurity?

   A) Improved mental health

   B) Increased economic growth

   C) Higher rates of chronic diseases

   D) Enhanced physical fitness

✓ **Self-evaluation check list**

Put a tick (√) against each of the following tasks, which you can perform. If you cannot perform any of these tasks, go back and read the lesson for that particular task.

I Can:

S.no	Questions	✓ Check
1	• Define food security.	
2	• Practice school-based gardening as one strategy of addressing food security.	

SECTION1.3. CREATING CONSCIOUS CITIZENS AND ENSURING SUSTAINABLE DEVELOPMENT

INTRODUCTION

☸ **Dear learner**, I hope you have gained some insights about food security, nutritional security, and food insecurity. Therefore, I hope you have understood the above topic very well. Now you are going to look about creating conscious citizens and ensuring sustainable developments. Before you learn about creating conscious citizens and ensuring sustainable developments, you will need to attempt the following questions that will be useful to keep in mind.

MINIMUM LEARNING COMPETENCIES

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

- Define conscious citizen.
- Explain the role of biology in creating a conscious citizen.
- Describe the meaning of a conscious global citizen.

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

☞ **Conscious citizen**: Person who understands interrelationships and places value on being fully human while connecting with a higher purpose

Dear learner, it is now time to define the term, as it is fundamental to understand how the concept is inter-linked with biology so that you will realize it better.

A conscious citizen is one who places value on being fully human while connecting with a higher purpose; one who values human life and a relationship with all living things, and one who takes the responsibility for transforming skills into action through ethical decision-making, to ultimately improve life and living on the planet. Biology has a vital role in creating conscious citizens by expanding awareness of social, global, and environmental conditions. Biology empowers conscious citizens to assume personal responsibility by engaging in and being committed to and taking the initiative for positive impact. Nowadays, the interplay of biology and technology (biotechnology) has become vital to facilitating sustainable development initiatives, in which conscious citizens will use biotechnology applications to improve life and living on the planet. Conscious citizen biologists develop innovative and cost-effective based technologies, which consume fewer resources, incorporate recycling, reuse components and reduce production of wastes, and use strategies for sustaining a greener earth and improving food production. Look at the **figure1.4**, which shows the model for sustainable development for more understanding.

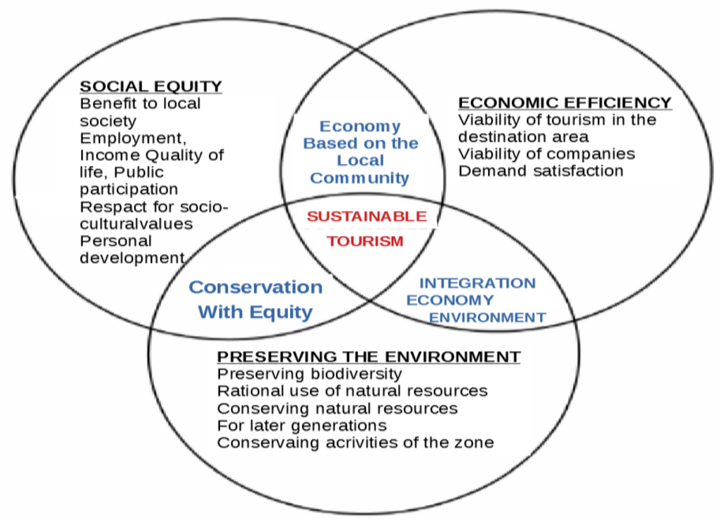


Figure1.4. A model for sustainable development

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

The conscious global citizens (biologists) in Ethiopia are involved in sustainable development through protecting, managing and monitoring the existing resources of our land including analyzing soil, water and air for chemical pollution. They are also concerned with finding ways to clean up pollution. Identifying, recording and monitoring the plants and animals that share the land we use.

🛠 Self-Test:

Write true if the statement is correct or false if not.

1. A conscious citizen is one who values human life and a relationship with all living things. (True/False)
2. Biology has no role in creating conscious citizens by expanding awareness of social, global, and environmental conditions. (True/False)
3. Biology empowers conscious citizens to assume personal responsibility by engaging in and being committed to and taking the initiative for positive impact. (True/False)
4. The interplay of biology and technology (biotechnology) has become vital to facilitating sustainable development initiatives. (True/False)
5. Conscious citizen biologists develop innovative and cost-effective based technologies, which consume more resources, incorporate recycling, reuse components and reduce production of wastes, and use strategies for sustaining a greener earth and improving food production. (True/False)

Activity 1.3

1. Read additional material on how students like you can be a conscious global citizen. Then prepare a report on your reading of conscious global citizenship and submit it to your tutor.

✓ **Self-evaluation check list**

Put a tick (√) against each of the following tasks, which you can perform. If you cannot perform any of these tasks, go back and read the lesson for that particular task.

I Can:

S.no	Questions	Check
1	• Define conscious citizen.	
2	• Explain the role of biology in creating a conscious citizen.	
3	• Describe the meaning of a conscious global	

SECTION1.4. APPLICATIONS IN BIOTECHNOLOGY

INTRODUCTION

❁ **Dear learner,** in the introductory part of this unit, you have learned how various applications of biology are important for our daily life. One of these applications is biotechnology, which we will explore in this section. Under this title, you will learn how biotechnology affects our everyday life in different ways.

MINIMUM LEARNING COMPETENCIES

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

- Define biotechnology
- Describe the importance of genetic engineering

What is biotechnology?

Dear learner, biotechnology is the use of living things, or substances from living things, to make products that help people. Some living things have been changed by adding genetic material from other living things through a process called **recombinant DNA technology**. These living things are called **genetically modified organisms (GMOs)**. If a living thing has genetic material from a different kind of living thing, it is called a transgenic organism. A piece of DNA from one kind of living thing that is put into another kind of living thing is called a transgene.

Why do we genetically engineer living organisms?

Organisms used in biotechnology may be genetically modified to make them more suitable. Crops can be modified to increase yields and to obtain novel products. Biotechnology can be used to prevent and mitigate contamination from industrial, agricultural and municipal wastes. Biotechnology can also be used in the diagnosis and treatment of disease in clinics and hospitals.

Genetically modified organism (GMO) is an animal, plant, or microbe whose DNA has been altered using genetic engineering techniques.

Recombinant DNA technology: Recombinant DNA technology is a technique used to manipulate and combine DNA sequences from different sources to create new genetic combinations.

Transgenic organisms: Transgenic organisms are organisms that have had foreign DNA introduced into their genome through genetic engineering techniques.

(i). Application of Biology for Food Processing and Production

In what ways does biology application contribute to food processing and production?

I hope you do so. In this topic I you are going to discuss the applications of biology in food processing and production. One of the roles of biology applications is in food processing and production. This method is used to increase food productivity using microorganisms. A technology that shows some promise in increasing world food productivity including **single-cell protein (SCP)**. SCP is produced from waste materials such as molasses from sugar refining, petroleum by-products, and agricultural wastes. In developed countries, an animal feed called **Pruteen** is produced by mass culture of the bacterium *Methylophilus methylotrophus*. **Mycoprotein**, a product made from fungus *Fusarium venenatum,* is also used there. The filamentous texture of this product makes it a likely candidate for producing meat substitutes for human consumption.

Single-cell protein (SCP) is a term that refers to edible unicellular microorganisms that are rich in protein. **SCP** can be used as an ingredient or a substitute for protein-rich foods for human consumption or animal feed.

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

Dear learners, besides that, Vitamins are also produced using biotechnology. Vitamin C was the first vitamin to be produced during a fermentation process by using **bacteria.** Previously, Vitamin B_{12} or cyanocobalamin and B_2 or Riboflavin were obtained from animal liver extract. But, nowadays the production of vitamin B12 involves fermentation by propionic bacteria. In nature, B_2 is found in cereals, vegetables, and yeast but the yield of B_2 can be enhanced hundred to three hundred times by using microbes.

(a). Dairy Products

Dear learner, you may be aware that many foods that we consume, such as Fresh cow's milk, yogurt, butter, & buttermilk are derived from animals. However, did you know that microorganisms to enhance their flavor, texture, nutrition, and shelf life also process these foods? This is an example of biotechnology applications that use living organisms or their products to create or modify foods for human consumption. I hope you find this topic interesting and relevant to your studies. Therefore, now you will look the application of biology in food processing.

What is the role of bacteria in fermented dairy products?

Microorganisms are used in making a wide variety of dairy products. Cultured buttermilk (Arera/Baaduu), popular in developed countries, is made by adding *Streptococcus cremoris* to pasteurized skim milk and allowing fermentation to occur until the desired consistency, flavor, and acidity are reached. Other organisms—*Streptococcus lactis, S. diacetylactis and*

Leuconostoc citrovorum, L. cremoris, or L. dextranicum—make buttermilk with different flavors because of variations in the fermentation products. Sour cream is made by adding one of these organisms to the cream. Yogurt is made by adding *Streptococcus thermophilus* and *Lactobacillus bulgaricus* to milk. These organisms still release other products in which yogurt has a different texture and flavor.

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

(b). Fermented Meats

Dear learner, similar to other fermented products meat is also fermented and consumed at different parts of this country. Microbes such as *Lactobacillus plantarum* and *Pediococcus cerevisiae* add flavor by fermenting meats such Wakalim (traditional fermented meat in Harari), salami, summer sausage, and Lebanon bologna. The heterolactic acid fermentation helps preserve the meat and also gives it a tangy flavor. Fungi such as *Penicillium* and *Aspergillus* that grow naturally on the surfaces of country hams, help to produce their distinctive flavor.

(c). The production of beer, wine, and spirits

I hope you know that fermentation is also done in traditional and industrial processes. So, here, you will look at biotechnology applications of microorganisms in industry.

Beer, wine, and spirits are different types of alcoholic beverages that are produced by fermenting and sometimes distilling various ingredients that contain sugar or carbohydrates. Then strains of Saccharomyces are the fermenters for all alcoholic beverages. Many different strains have been developed, each having distinctive characteristics. Both the organisms and how they have used are carefully guarded brewers' secrets.

☞ **Distillation:** is a method of separates alcohol and other volatile substances from solid and nonvolatile substances.

Strains: Strain is a distinguishable, stable genetic variant of a species.

Beer is made from grains, such as barley, wheat, corn, or rice, which are mashed with hot water to release their sugars. The sugary liquid, called wort, is then boiled with hops and other flavorings, and fermented with yeast to produce alcohol and carbon dioxide.

Which microorganisms are important in beer, wine, and spirits?

Wine is made from fruits, such as grapes, apples, or berries that are crushed and pressed to extract their juice. The juice is then fermented with yeast to produce alcohol and carbon dioxide. Some wines are aged in barrels or bottles to develop their flavor and color.

Spirits are made from either beer or wine that is distilled to increase their alcohol content. Distillation involves heating the fermented liquid until the alcohol vaporizes and then condensing it back into a liquid. The resulting spirit is usually clear and strong, and can be flavored with herbs, spices, fruits, or wood.

(d). **Bread making**

Dear learner, you might have observed how bread is made at home. Do you know the reasons behind its leavening, softness, and delicious aroma and flavor? Therefore, you will look at this one in more detail here.

Microorganisms accomplish three functions in bread making:

1. leavening the flour-based dough, **2.** Imparting flavor and odor, and

3. Conditioning the dough to make it workable.

Bread making is the process of creating bread from basic ingredients such as flour, water, yeast, and salt. It is a centuries-old culinary tradition that holds cultural significance worldwide. Fermentation is a fascinating process that plays a crucial role in creating the delightful loaves we enjoy.

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

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

Dear learner, in the context of bread making, fermentation plays a pivotal role in shaping its **sensory profile**. Chemical compounds interact during fermentation, resulting in a complex **interplay of flavors and aromas**. Therefore, bread making transcends mere sustenance. It is a blends of tradition, creativity, and nourishment that brings people together.

Generally, benefits of Fermentation in Bread Making include:

- **Flavor Enhancement**: Fermentation yields more flavorful and aromatic breads.
- **Improved Dough Workability**: The dough becomes easier to handle during kneading.

- **Nutrient Release**: Fermentation releases vitamins, minerals, and other nutrients into the dough.
- **Digestibility:** Proper fermentation improves the digestibility of bread.
- **Reduced Anti-Nutrients**: It reduces anti-nutrients like lectins, oxalates, phytates, and cyanogenic glycosides.
- **Lower Glycemic Index**: Fermented bread has a lower glycemic index.
- **Faster Cooking:** Fermented dough cooks faster.

In summary, bread fermentation is not just about fluffiness; it is a fundamental process that contributes to taste, texture, and overall quality.

Activity 1.4

Please take a moment to review the information provided below. In the list, you will find various local fermentation products that are made using biotechnology and different processes. Your task is to identify the type of biotechnology and the processes used for each product. Additionally, please describe the microorganisms involved in their production and explain the types of metabolites or bio-products produced by these microorganisms.

"Shameta, Bulla, and Siljo".

1. What are the benefits and drawbacks of using natural fermentation versus starter cultures in the production of traditional fermented food and beverages? Give some examples of Ethiopian products that use either method and explain how they differ in quality and safety.

Figure 1.5. Sourdough bread

Activity 1.5

- Describe the health and nutrient benefits of fermented foods as compared to the non-fermented ones, give common examples of fermented foods in your locality

? What are bioreactors? How is bioreactor important for microorganisms to able to perform their desired function with limited production of impurities?

(ii). Application of Biology in Genetic Engineering

Dear learner, Can you explain genetic engineering? **Genetic engineering** is the process of transferring DNA from one organism into another for a genetic modification or the production of a transgenic organism. Specific applications of genetic engineering are abundant and increasing rapidly in number. Genetic engineering is being used in the production of pharmaceuticals, gene therapy, and the development of transgenic plants and animals.

Self-test

1. List other technological application of biology you know and explain their importance.
2. Why is bioengineering important for developing countries such as Ethiopia?

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

Dear learner, animals can also be genetically modified (transgenic animals) for valuable traits. Therefore, animal breeding focuses on the genetic value of livestock. Selecting animals for breeding with superior traits in growth rate, and production of eggs, meat, milk, or wool, as well as other desirable traits has revolutionized livestock and plant production worldwide (**See Figure 1.6**).

There are many potential applications of transgenic methodology in developing new and improved strains of livestock. The practical applications of transgenic technology in livestock production include enhancing the prolificacy, reproductive, increasing feed utilization, and growth rate, improving carcass composition, improving milk production and/or composition, modification of hair or fiber, and increasing disease resistant animals. The development of transgenic farm animals will allow more flexibility in the direct genetic manipulation of livestock. Gene transfer is a relatively rapid way of altering the genome of domestic livestock

Figure 1.6. Biotechnology improves the quality of breeds

Dear learner, what is the main benefit of animal genetic engineering for public health?

(iii). Tissue culture

Dear learner, do you know what tissue culture is? **Tissue culture** is a technique used to rapidly propagate plants in large quantities. It is a method of biological research where fragments of tissue from an animal or plant are transferred to an artificial environment where they can survive and function. The cultured tissue can be a single cell, a population of cells, or a whole or part of an organ. Plants that can be produced in large quantities using this technique include palm trees, orchids, bananas, and carrots. By utilizing tissue culture, a large quantity of food with desired quality can be produced in a relatively small area. Therefore, tissue culture is considered an important biotechnology for developing countries as it allows for the production of disease-free, high-quality planting material and the rapid production of uniform plants **(**see **Figure 1.7)**.

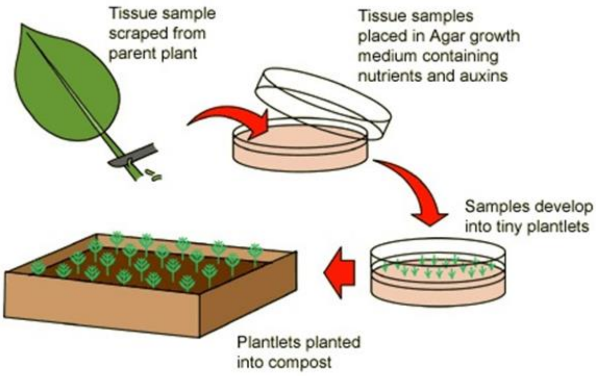


Figure 1.7. Tissue culture

Activity 1.6.

1. How can biotechnology be applied in bio-fortification of fruits and grains to enhance nutrient availability and quality? Provide examples of bio-fortified crops in Ethiopia.

Dear learner, Biofortification is a powerful approach that leverages biotechnology to enhance the nutrient content of crops, making them more nutritious and addressing micronutrient deficiencies, often referred to as "**hidden hunger**."

Biofortification Strategies:

- **Agronomic Biofortification**: This method involves adjusting soil conditions and nutrient availability to enhance crop nutrient content. It includes practices like soil amendment, fertilization, and irrigation management.
- **Plant Breeding**: Traditional breeding techniques are used to develop crop varieties with higher levels of specific nutrients. Breeders select and cross plants to create new varieties that naturally accumulate more vitamins and minerals.
- **Transgenic Approaches**: Genetic modification introduces specific genes into crops to enhance nutrient content. For example, genes responsible for producing vitamin A or iron can be inserted into crops.
- **Omics Technology**: Advanced techniques like genomics, proteomics, and metabolomics are used to identify and manipulate genes related to nutrient accumulation1.

Examples of Biofortified Crops in Ethiopia:

Vitamin-A Maize: Biofortified maize varieties with increased levels of provitamin A (beta-carotene) are being developed. These varieties can help combat vitamin A deficiency.

Zinc Wheat: Wheat varieties enriched with zinc are essential for addressing zinc deficiency, which affects human health and crop productivity.

Iron Irish Potato: Biofortified potatoes with higher iron content contribute to better nutrition and health outcomes.

Iron and Zinc Lentils: Lentils are staple legumes in Ethiopia. Biofortified lentils can provide essential iron and zinc to combat deficiencies.

Impact and Challenges:

Biofortification has the potential to improve public health by reducing nutrient deficiencies.

Challenges include ensuring consumer acceptance, scaling up production, and integrating biofortified crops into existing agricultural systems.

Generally, biotechnology-driven biofortification holds promise for enhancing nutrient availability and quality in fruits and grains, contributing to better health outcomes for communities, especially in regions like Ethiopia where malnutrition remains a challenge.

(iv). Health and wellbeing's

Dear learner, you may have already learned some basic concepts about how biology impacts health during your previous classes from grades 9 to 11. However, now you will delve deeper into how biology influences your overall health and wellbeing. Please carefully read the following **subheading (a-c)** for detailed information.

(a). The manufacture of antibiotics

Do you think microorganisms make antibiotics? How?

Dear learner, some microorganisms make complex organic compounds, called **antibiotics** that we want to use. These are not the same as their fermentation products. Bacteria or fungi that live in the soil make many of the antibiotics we use. We do not know why they make these chemicals. Some people think that the chemicals help them to fight for food with other organisms, but there is no proof for this idea. Actinomycetes are a type of bacteria that look like tiny mold fungi. They make many antibiotics. One of them is Streptomyces, which makes the antibiotic streptomycin.

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

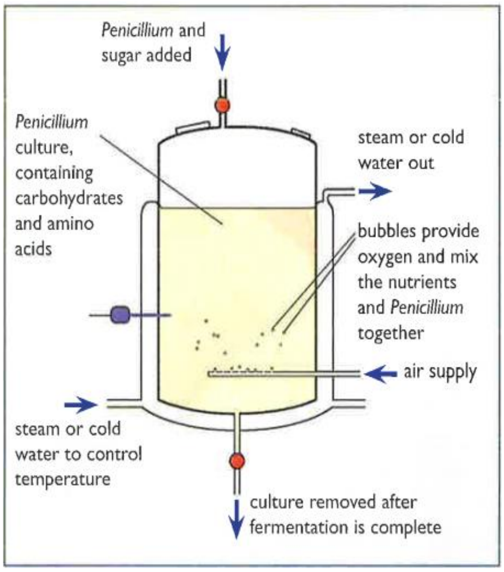


Figure 1.8. A fermenter used for producing penicillin.

Do you know the mechanism by which antibiotics kill microorganisms?

Dear learner, antibiotics attack bacteria in various ways. Some disrupt the production of the **cell wall**, Inhibition of **nucleic acid synthesis**, or stopping reproduction altogether. Others interfere with protein synthesis halting bacterial growth. Antibiotics that prevent reproduction are called **bacteriostatic**, while those that kill bacteria are called **bactericidal**. Unlike bacteria, animal cells do not have cell walls, and their protein production structures differ. Therefore, antibiotics do not harm human cells, though they may cause side effects such as allergic reactions.

☞ **Antibiotics:** are substances that can inhibit or kill microorganisms, especially bacteria.

Bacteriocidal: destroying bacteria

Bacteriostatic: preventing the growth or multiplication of bacteria, without necessarily killing them

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

b).Biosensors

? What is the importance of biosensor in medicine?

Dear learner, **Biosensor production** is a rapidly growing field in biotechnology that is attracting significant global scientific attention. In this area of bioelectronics, electrodes are connected to living microorganisms (or their enzymes or organelles), and biosensors convert biological reactions into electric currents. Biosensors have a wide range of applications, such as measuring specific components in beer, monitoring pollutants, detecting flavor compounds in food and measuring the concentration of substances in various environments. Examples of substances that biosensors can measure include **glucose, acetic acid, glutamic acid, ethanol, and biochemical oxygen demand**. Additionally, biosensors have been used to measure cephalosporin, nicotinic acid, and some B vitamins. Recently, biosensors utilizing immunochemical-based detection systems have been developed. These new biosensors are capable of detecting **pathogens, herbicides, toxins, proteins, and DNA**, often using a **streptavidin-biotin** recognition system.

☞ **A biosensor** is an analytical device that combines a biological component with a physicochemical detector to measure the presence of a chemical substance.

Furthermore, one of the most interesting recent developments using these approaches is a handheld **aflatoxin** detection system, which is used to monitor food quality. This system is based on a new column-based immunoaffinity fluorometric procedure. The automated unit can conduct 100 measurements before needing to be recharged. It can detect **aflatoxins** ranging from 0.1 to 50 ppb in a 1.0 ml sample in less than 2 minutes. Rapid advances are being made in all areas of biosensor technology, including significant improvements in the stability and durability of these units, making them more portable and sensitive. These units can also measure microorganisms and metabolites such as **glucose**, helping to meet critical needs in modern medicine.

Activity 1.7.

1. What are the advantages and disadvantages of using enzymes as bioreceptors in biosensors? Give some examples of enzyme-based biosensors and their applications.
2. How do optical biosensors work? What are the different types of optical biosensors and how do they differ in their detection methods? Give some examples of optical biosensors and their applications.

Self-test

Choose the appropriate answer from the given alternatives

1. What is the primary function of biosensors in the field of bioelectronics?
   a) Measuring specific components in beer
   b) Monitoring pollutants
   c) Detecting flavor compounds in food
   d) Converting biological reactions into electric currents
2. Which substances can biosensors measure?
   a) Glucose, acetic acid, and glutamic acid
   b) Ethanol and biochemical oxygen demand
   c) Cephalosporin, nicotinic acid, and some B vitamins
   d) All of the above

3. How quickly can the handheld aflatoxin detection system detect aflatoxins in a 1.0 ml sample?
    a) Less than 1 minute
    b) 2 minutes
    c) 5 minutes
    d) 10 minutes
4. What type of detection system do the recently developed biosensors utilize?
    a) Immunochemical-based
    b) Fluorometric-based
    c) Streptavidin-biotin-based
    d) All of the above
5. What are biosensors capable of detecting using the streptavidin-biotin recognition system?
    a) Pathogens
    b) Herbicides
    c) Toxins
    d) Proteins and DNA

c). Forensic Science

What is forensic science?

Dear learner, Forensic science is a scientific method and technique used to solve legal problems, such as crimes or civil disputes. Forensic biologists inspect crime scenes to examine potential sources of evidence, such as blood, saliva, and hair. They then analyze these specimens in a laboratory, focusing on **DNA analysis** (**See Figure1.9**). Additionally, fingerprints are important tools in investigating crime and determining paternity in cases involving children. This is because each individual has unique fingerprints that remain constant throughout life. Based on their investigations, forensic biologists write up their findings in technical reports and are often called upon to testify in court. The data obtained from forensic findings is used to investigate the related transgression, and these facts are presented in court to help prosecute the criminal. These days, bioinformatics is widely accepted in the field of forensic science. With the help of computational tools, it has become easier and more reliable to gather evidence related to a particular crime scene.

Activity 1.8

1. How do forensic scientists use DNA analysis to identify suspects or victims of crimes? What are the advantages and limitations of DNA analysis in forensic investigations? Give some examples of cases where DNA analysis was used to solve crimes or exonerate innocent people.

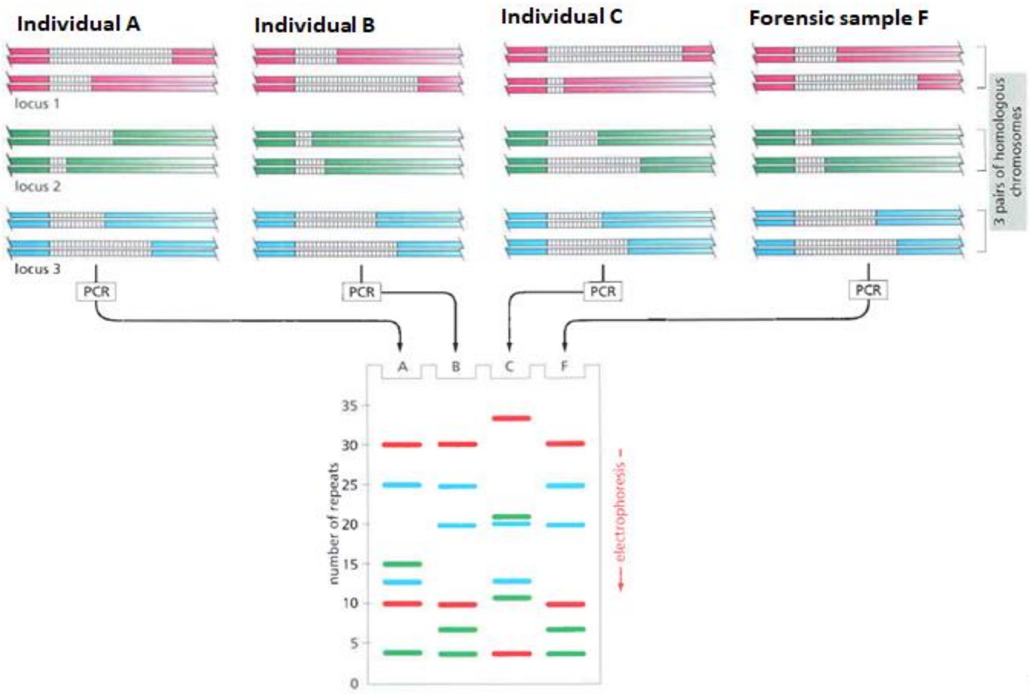


Figure 1.9. PCR as forensic science tools

Additionally, when examining the variability at 5-10 different **Variable Number of Tandem Repeat (VNTR)** loci, the odds that two random individuals would share the same genetic pattern by chance can be approximately 1 in 10 billion. In the case shown here, individuals A and C can be eliminated from further inquiries whereas individual **B remains a clear suspect** for committing the crime. A similar approach is now routinely used for paternity testing. Please see **Figure 1.10**, "**PCR in Forensic Application for the gel electrophoresis**" results of two suspected paternity tests.

? What is the name of the regions of the genome that vary widely between different individuals and are used to identify suspects in forensic cases?

a) VNTRs (Variable Number Tandem Repeats) b). SNPs (Single Nucleotide Polymorphisms) c). STRs (Short Tandem Repeats) d). *All of the above*

Figure 1.10. PCR in forensic application.

Therefore, the suspected person (DNA of suspected 2) is the father of the baby (victim).

Self-Test

True/False Item: Write true if the statement is correct and false if the statement is incorrect.

1. Forensic science is only used for criminal investigations.
2. Forensic scientists can use DNA analysis to determine the identity of a person or their relatives.
3. Forensic scientists always collect the evidence themselves from the crime scene.
4. Forensic scientists can use fingerprints to match a person to a crime scene or a weapon.
5. Forensic science is a new field that emerged in the 20th century.

Activity 1.9.

- Write a short note on the role of biological knowledge in forensic science and report it to your tutor.

(V). Applications in biomining

1). Microbiological mining

How microorganisms are important in Bio-mining?

Dear learner, Biohydrometallurgy is the use of microbes to extract metals from ores that are **less rich in minerals**. This is a new field that emerged due to the depletion of high-grade ores. Some bacteria, such as *Thiobacillus ferrooxidans*, can oxidize the sulfur that binds metals in sulfide minerals, making the metals soluble and easy to recover. This process can be applied to copper, iron, uranium, and other metals. Some bacteria can work together or with other organisms to degrade minerals that they cannot degrade alone. For example, *Leptospirillum ferrooxidans* and *T. organoparus* can degrade pyrite and chalcopyrite. Other bacteria may be used to mine arsenic, lead, zinc, cobalt, and gold in the future. However, the use of microbes in mining is not very common yet.

Self-Test

True/False Item: Write True if the statement is correct or false if a statement is incorrect.

1. Biomining can be used for bioremediation, biohydrometallurgy, and in situ mining.
2. Bacteria can only perform Biomining, not by fungi or other organisms.
3. Biomining can extract metals such as gold, copper, nickel, uranium, and thorium.

(Vi). Application in the Environment

Dear learner, you may have some background knowledge of environmental pollution from radio, TV or your past classes. However, do you know what causes it? In this section, you will learn more about the application of biology in the protection of environment. Some of the applications are given below.

A). Solid waste treatment: composting and landfill

Dear learner, do you know what solid waste is and its mechanisms of treatment? Most solid waste ends up in landfills, which are huge holes in the ground where refuse is deposited to prevent it from being a hazard. The non-biodegradable components, such as metals, plastics, and rubble remain there more or less indefinitely. However, biodegradable materials like food waste, textiles, and paper undergo a decomposition process over time. The rate at which this happens depends on the nature of the waste and the conditions of the landfill. The decomposition process can take several decades, with aerobic processes transitioning to anaerobic ones, resulting in the generation of methane.

Modern landfill sites have a system in place to remove methane to prevent it from becoming a fire or explosion hazard, and it may be used as a fuel source. Many householders separate organic waste items such as vegetable peelings and grass cuttings to make compost. This practice not only provides a useful gardening supplement, but also significantly reduces the volume of material that needs to be disposed of by other means.

Fungi and bacteria, particularly actinomycetes, break down the organic matter to produce CO2, water and humus, a relatively stable organic product. Compost is not a fertilizer, as its nitrogen content is not high, but it provides nutrients to soil and generally, helps improve its condition. Composting is carried out on a large scale by local authorities using waste generated in municipal parks and gardens.

Self-Test

1) What are the advantages and disadvantages of landfill sites as a method of solid waste disposal? Provide examples of biodegradable and non-biodegradable materials and explain how they affect the decomposition process in landfills.
2) How does composting help to reduce the volume of solid waste and improve the soil condition? Describe the role of fungi, bacteria, and

actinomycetes in the composting process and explain why compost is not a fertilizer.

3) Compare and contrast aerobic and anaerobic decomposition processes in terms of their products, rates, and environmental impacts. How is methane generated and utilized in modern landfill sites?
4) What are some alternative methods of solid waste disposal besides landfill sites and composting? Evaluate their feasibility, efficiency, and sustainability in different contexts.
5) How can householders and local authorities collaborate to reduce the amount of solid waste generated and disposed of? Discuss some strategies and initiatives that can promote waste reduction, reuse, and recycling.

Activity 1.10

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

B). Wastewater treatment

How is wastewater treated?

Dear learner, the goal of wastewater treatment is to get rid of unwanted substances and harmful microbes so that the water can safely go into a watercourse like a river or stream. More cleaning steps are needed before it can be used as drinking water. Wastewater treatment is very important for any developed society, and it lowers the chance of getting diseases from water such as cholera. **Wastewater** can come from homes or businesses; very poisonous industrial wastes may need to be treated first before going into a water treatment system. **Sewage** is the word used to describe liquid wastes that have faecal matter (from humans or animals). The main way to judge how well the treatment process works is by how much it lowers the wastewater's **biochemical oxygen demand (BOD)**. This is how much oxygen the microbes need to break down its organic content. A high **BOD** takes away oxygen from water, which shows that the water is polluted.

What are the three stages of wastewater treatment? Explain each stage.

Wastewater treatment usually occurs at different stages. The first of which (**primary treatment**) is purely physical, and involves the removal of floating objects followed by sedimentation, a process that removes up to one-third of the BOD value. Secondary treatment involves microbial oxidation, which lead to a substantial further reduction in BOD. This may take one of two forms, both of which are aerobic, the traditional *trickling filter* and the more recent *activated sludge* process (See Figure 1.7.). In the former, the wastewater is passed slowly over beds of stones or pieces of molded plastic. These develop a biofilm comprising bacteria, protozoans, fungi and algae, and the resulting treated water has its BOD reduced by some 80–85%.

Activated sludge facilities achieve an even **higher degree of BOD reduction**. Here, the wastewater is aerated in tanks that have been seeded with a mixed microbial sludge. The main component of this is the bacterium *Zoogloea,* which secretes slime, forming aggregates called *flocs*, around which other microorganisms such as protozoans attach. Some of the water's organic content is not immediately oxidized, but becomes incorporated into the flocs. After a few hours' residence in the tank, the sludge is allowed to settle out, and the treated water passes out of the system. Before being discharged to a watercourse, it is treated with chlorine to remove any pathogenic microorganisms that may remain. The principal operating problem encountered with activated sludge is that of *bulking*. This is caused by filamentous bacteria such as *Sphaerotilus natans*, which prevent the sludge from settling properly and consequently passing out with the treated water.

Both **secondary treatment** processes result in some surplus sludge, which undergoes *anaerobic digestion*, resulting in the production of methane and CO_2. The methane can be used as a fuel to power the plant, and any remaining sludge is dewatered and used as a soil conditioner. Care must be taken in this context, however, that the sludge does not contain toxic heavy metals.

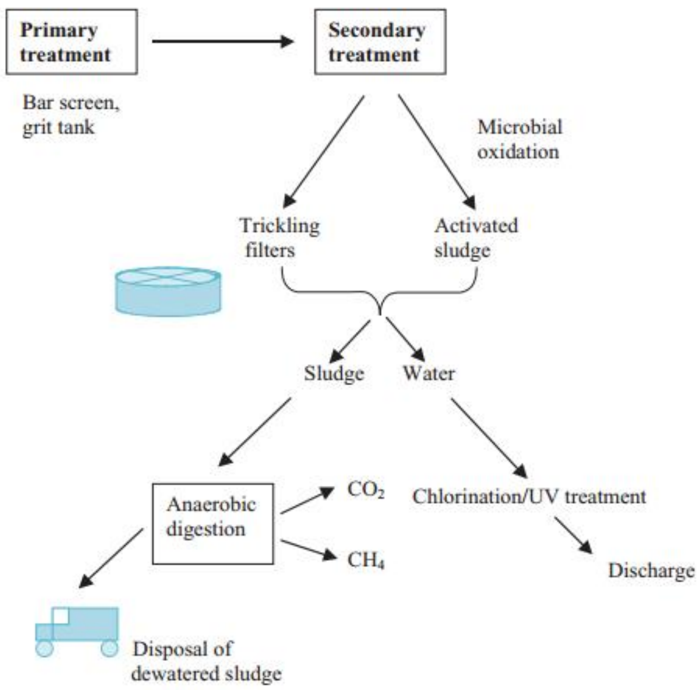


Figure 1.11. The role of microoorganisms in wastewater treatment

Self-Test

Choose the appropriate answer from the given alternatives

1. What is the main purpose of wastewater treatment?
   A) To remove impurities from wastewater before it reaches natural water bodies or is reused
   B) To produce biogas and sludge from wastewater
   C) To increase the water demand and supply gap
   D) To generate electricity from wastewater
2. What are the three stages of wastewater treatment?
   A) Primary, secondary, and tertiary
   B) Screening, sedimentation, and disinfection

C) Coagulation, flocculation, and filtration
D) Aeration, nitrification, and denitrification

3. What is the difference between aerobic and anaerobic processes in wastewater treatment?
   A) Aerobic processes use oxygen while anaerobic processes do not
   B) Aerobic processes produce methane while anaerobic processes do not
   C) Aerobic processes are faster while anaerobic processes are slower
   D) All of the above
4. What is the main by-product of wastewater treatment plants?
   A) Sludge B). Biogas C). Effluent D). None of the above

C). Bioremediation

Do only microorganisms perform bioremediation?

Dear learner, Bioremediation is the process of using living organisms or their byproducts to detoxify and break down environmental pollutants. The most common way to break down pollutants is through **biodegradation**, which involves the help of **saprophytic microbes**. Scientists also use **genetically engineered** bacteria that are metabolically designed to break down toxic pollutants into harmless compounds. For example, bacteria that are resistant to mercury can transform metallic mercury, which is harmful to the nervous system, into a non-toxic compound.

Furthermore, when microbes are used for bioremediation, **enzymes** produced by the microbe modify the **toxic pollutant** by changing its structure. This process is known as **biotransformation**. **Biotransformation** leads to biodegradation, where the toxic pollutant is broken down into less complex, non-toxic metabolites. **Bioremediation** can also occur through biotransformation without **biodegradation**, such as when toxic heavy metals are made less harmful through oxidation or reduction reactions carried out by microorganisms.

☞ **Bioremediation**: Bioremediation is a process that uses living organisms, usually microorganisms, to remove or degrade pollutants from the environment.

Biotransformation: Biotransformation is the process of modifying a chemical compound or a mixture of chemical compounds using biological agents, such as microorganisms, enzymes, or plants.

Biodegradation: Biodegradation is the process of decomposing organic matter or substances by the action of living organisms, especially microorganisms.

D). Biofuels

Dear learner, do you know what biofuel is? **Biofuel** is a fuel derived from biological materials, such as **plants, algae, or animal waste**. The need to become independent of **fossil fuels** is driven by both political and environmental concerns. This has accelerated interest in and the use of biofuels - fuel (chiefly ethanol) that is obtained by the fermentation of plant material. While corn is currently the substrate of choice, the use of crop residues could significantly boost biofuel yields. **Crop residues** are the plant material that consists of cellulose and hemicellulose usually left in the field after harvest. These polysaccharides are polymers of five different hexoses and pentoses: **glucose, xylose, mannose, galactose, and arabinose**. While no microorganism naturally ferments all five sugars, a ***Saccharomyces cerevisiae*** strain has been engineered to ferment xylose. An E. coli strain that expresses ***Zymomonas mobilis*** genes is able to ferment all these sugars.

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

E). Biogas production

Which organisms are the key participants of Biogas production?

Dear learner, Bacteria and archaeans in **fermenters** produce **biogas** from organic matter. **Biogas** is a combustible gas created through the anaerobic breakdown of organic matter such as manure, waste plant matter from crops and household organic waste by microorganisms. Depending on the fermenter's construction, biogas is primarily methane with some carbon dioxide though other gases may also be present.

Three different communities of anaerobic microbes are necessary for this process. The first group converts the raw organic waste into a mixture of organic acids, alcohol, hydrogen and carbon dioxide. The second group uses the organic acids and alcohol from the first stage to produce acetate, carbon dioxide and hydrogen. These first two communities consist of Eubacteria. The last group is made up of Archaea known as methanogens. Methanogens produce methane through one of the two reactions. The methanogens produce methane by one of the following two reactions:

$CO_2 + 4H_2 \rightarrow CH_4 + 2H_2O$

(reduction of carbon dioxide to methane)

$CH_3COOH \rightarrow CH_4 + CO_2$

(splitting ethanoic acid to form methane and carbon dioxide)

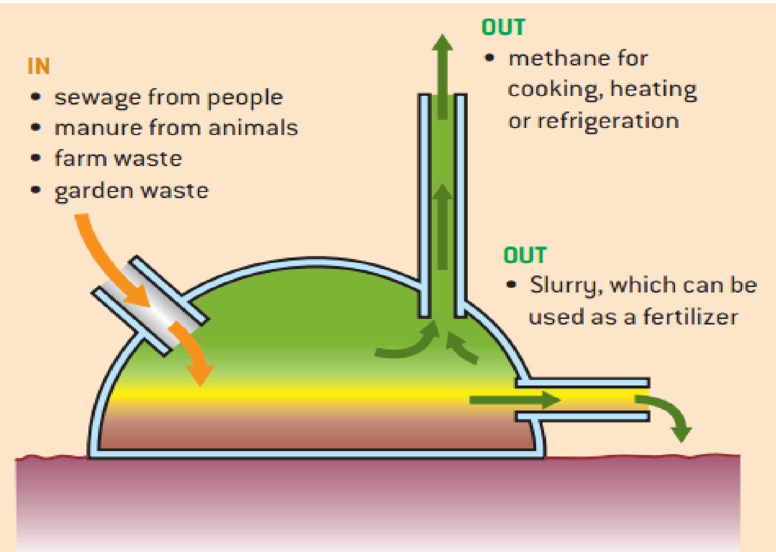


Figure 1.12. Methane generator. Conditions inside must be anaerobic

Advantages of biogas

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

C) Composting

Dear learner, what is composting? Composting is an aerobic microbial driven process that converts solid organic wastes into a stable, sanitary, humus-like material that has been considerably reduced in bulk and can be safely returned to the environment. It is, in effect, a low-moisture, solid substrate fermentation process as previously discussed. To be totally effective, it should only use as substrates readily decomposable solid organic waste. In large-scale operations using largely domestic solid organic wastes, the final product is mostly used for soil improvement, but in more specialized operations, in using specific organic raw substrates (straw, animal manures, etc.), the final product can become the substrate for the worldwide commercial production of the mushroom *Agaricus bisporus*.

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

> What is the source of the microorganisms that do composting?

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

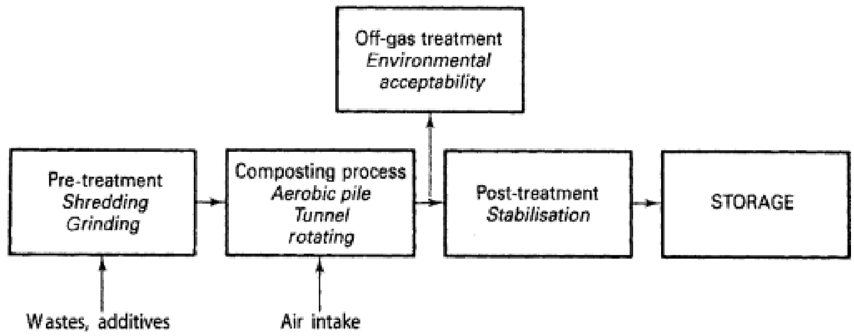


Figure 1.13. flow chart compositing plants processes

Self-Test

In your exercise book, draw a table like the one this and fill in the space provided with the appropriate terms from the top of the table.

A. Bioremediation, B. Biofuel , C. Biogas, D. Composting		
1	A process of converting organic waste into a nutrient-rich soil conditioner by aerobic decomposition.	
2	A fuel derived from biological sources such as plants, animals or microorganisms.	
3	A process of using microorganisms to break down environmental contaminants into less harmful substances.	

4	A gas mixture produced by anaerobic digestion of organic matter, mainly consisting of methane and carbon dioxide.	

(Vi). Application in Industry

Dear learner, you might have learned some basics of enzyme properties, activities, types and roles in your grade 11 biology course. In this section, you will dive deeper into the various applications and functions of biological enzymes in industry. Listed below are some of the function and types of an enzymes.

A).Enzymes

? What do you think the sources of an enzymes used in industry?

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

Some commercial uses of enzymes are listed below.

- **Proteases**: In washing powders for dissolving stains from egg, milk and blood; removing hair from animal hides; cheese manufacture; tenderizing meat.

● **Lipases**: Flavors enhancer in cheese; in washing powders for removal of fatty stains.

● **Pectinases**: Clarification of fruit juices; maximizing juice extraction.

● **Amylases**: Production of glucose from starch.

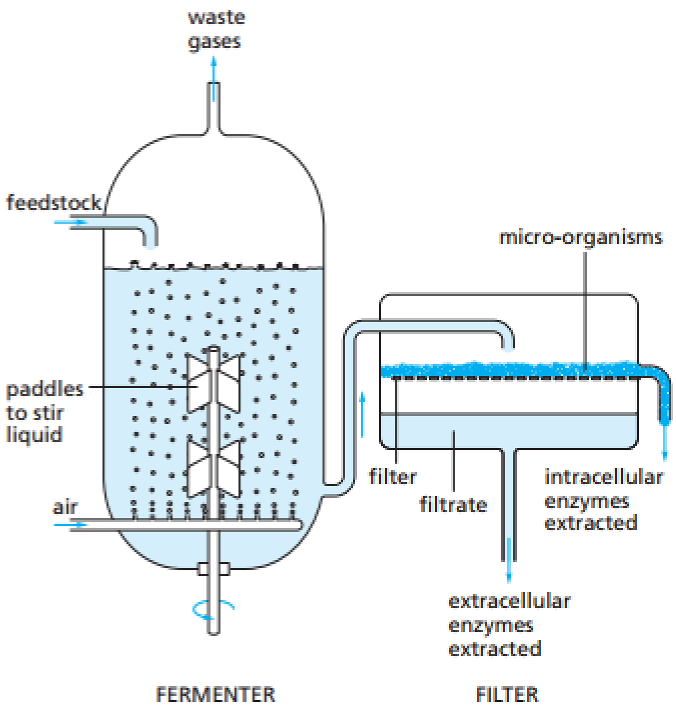


Figure 1.14. Principles of enzyme production from micro-organisms

B). Biological washing powders

What kind of enzymes do biological washing powders contain?

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

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

Self-test

Write True if the statement is correct or false if the statement is incorrect

1. Enzymes are biological molecules that catalyze (increase the rates of) chemical reactions.
2. Enzymes are not selective for their substrates and can work on any type of molecule.
3. Enzymes from extremophilic microorganisms have higher activity and stability under unconventional conditions.
4. Enzymes are used in the textile industry to soften fabric and improve color.
5. Industrial biotechnology is also known as white biotechnology.
6. Enzymes in washing powders help to break down stains of starch or protein origin.
7. Enzymes in washing powders are specific and will only work on one type of molecule.
8. Enzymes in washing powders are not affected by temperature and pH.

Vii). Applications in agriculture

Dear learner, I believe you have acquired an understanding of the role of biology in various fields from the preceding lessons. One of those fields is agriculture. So, in this topic, you will explore the role of biology in agriculture. Here are some of the roles of biology in agriculture.

A) Biopesticides

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

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

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

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

B). The use of Ti plasmid as a vector

What is Ti plasmid?

A method to transfer transgenes into plants is to use *Agrobacterium tumefaciens*. This is a type of bacteria that has a **plasmid**, called the **Ti plasmid** that makes tumours in the plants it infects. The gene for glyphosate resistance is added to the Ti plasmid along with a gene for antibiotic resistance. The modified plasmid is then put back into an *A. tumefaciens* bacterium. Plant cells are then exposed to the transgenic bacterium and grown on a plate with antibiotic. The only plant cells that survive are those that have taken up the plasmid. The others are killed by antibiotic.

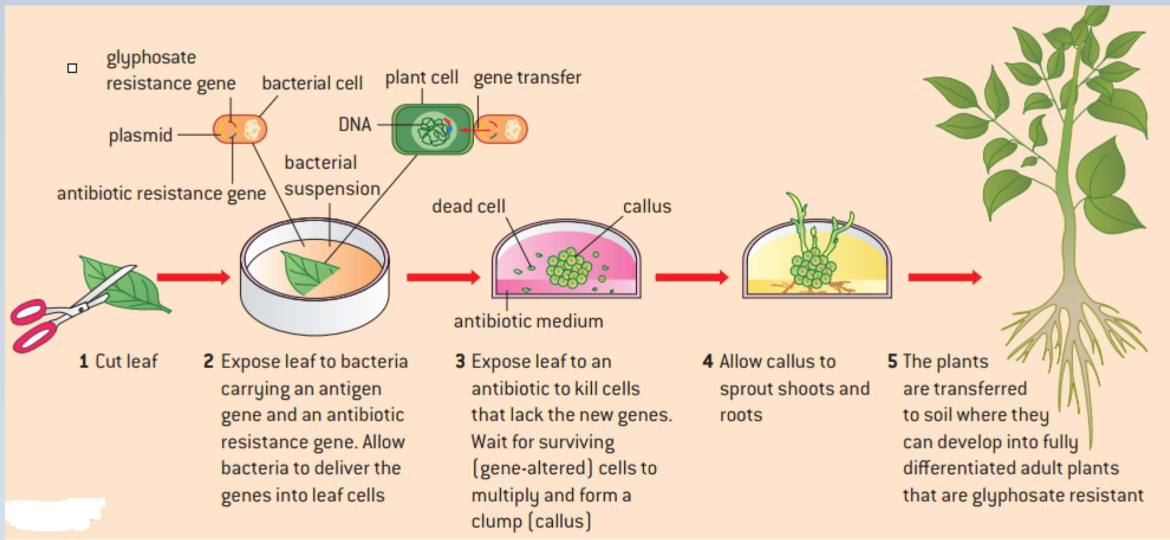


Figure 1.15. The use of Ti palmids as vector

🛠 **Self-test**

Write True if a statement is correct and false if a statement is incorrect

1. Ti plasmid is a plasmid that causes tumours in plants.
2. Ti plasmid is a plasmid that comes from a fungus.
3. Ti plasmid can be used to transfer genes into plant cells.
4. Ti plasmid can be used to transfer genes into animal cells.
5. Ti plasmid can be modified to include genes for resistance to herbicides or antibiotics.

C). Insect-resistant crops

Dear learner, do you know why plants are resistant to insects? if you don't know, you'll see more about it under this topic.

Therefore, another important agricultural development is that of genetically modified plants protected against attack by pests. Maize is protected against the corn borer, which eats the leaves of the plants and then burrows into the stalk, eating its way upwards until the plant cannot support the ear.

Cotton is protected against pests such as the boll weevil (See Figure 1.13). In both plants, yield is improved.

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

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

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

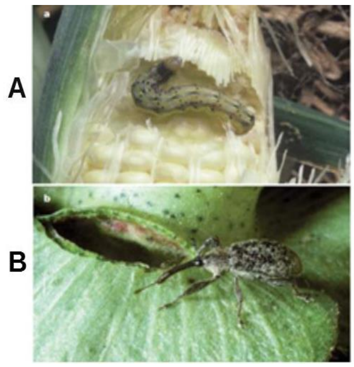


Figure 1.16. a). Corn borer, b). Boll weevil

? What causes plant resistant to insect**?**

D). Pest Resistant Crops

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

E). Transgenic Animals

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

F). Transgenic Plants

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

Attention: Transgenic crops are being created that resist disease, are tolerant of herbicides and drought, and have improved nutritional quality. Plants are also being used to produce pharmaceuticals, and domesticated animals are being genetically modified to produce biologically active compounds.

Figure 1.17. Corn

Plants that have received recombinant DNA from other species are called transgenic plants. Because they are not natural, transgenic plants and other GMOs are closely monitored by government agencies to ensure that they are fit for human consumption and do not endanger other plant and animal life. Because foreign genes can spread to other species in the environment, extensive testing is required to ensure ecological stability. Staples such as corn, potatoes, and tomatoes were the first crop plants to be genetically engineered.

B). Pest resistance

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

C). Herbicide resistance

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

Self-test

Write True if the statement is correct and False if the statement is incorrect.

1. Pest control is one of the primary applications of biology in agriculture.
2. Selective breeding seeks to improve traits such as taste, color, disease resistance and productivity.
3. Biotechnology is a new science that has no ancient roots.
4. Food preservation refers to the processes to stop food spoilage due to microbial action.
5. Agriculture is not related to biology because it involves non-living things.

Check list 1: boxes provided for each of the following terms or phrases. Put a right mark if you are familiar with them or go back and read again if you are not.

- Genes
- Transgenic plants
- BT-Cotton
- Ti plasmid
- Tumours
- Greenhouse

Viii. Biological warfare

Dear learner, ever heard of biological warfare? What do you think of it? We will look at it in more detail in this section.

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

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

Self-test

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

Self-test

1. Anthrax is a type of bacteria that can be used as a biological weapon. (True , False)
2. What is the term for the process of spreading biological agents over a large area?
   a. Dissemination c. Dispersion
   b. Diffusion d. Distribution
3. Which of the following is a potential advantage of using biological weapons?
   a. They are easy to detect and identify
   b. They are cheap and readily available
   c. They are environmentally friendly and biodegradable
   d. They are selective and target-specific

Unit Summary

- Biotechnology is the application of scientific knowledge by industries that produce biological products like food supplements, enzymes, and drugs.
- Yeasts (Fungi), moulds (Fungi) and bacteria are important microorganisms used in industries.
- Fermentation is a process by which sugar is converted into alcohol and CO_2 by yeast.
- Fermentation by the yeast Saccharomyces yields beer and that by Lactobacillus, yields butter milk.
- Tissue culture, a method of biological research in which fragments of tissue from an animal or plant are transferred to an artificial environment in which they can continue to survive and function. The cultured tissue may consist of a single cell, a population of cells, or a whole or part of an organ.
- Genetic engineering involves the transfer of genes from one organism to an unrelated species. Genetic engineering is being used in the production of pharmaceuticals, gene therapy, and the development of transgenic plants and animals.
- Wastewater may come from domestic or commercial sources; highly toxic industrial effluents may require pretreatment before entering a water

treatment system. *Sewage* is the term used to describe liquid wastes that contain faecal matter (human or animal).

- Biogas is made by the action of methanogenic bacteria on waste matter such as the faeces of humans or of cattle.
- Transgenic plants may be obtained by using the plasmid of the bacterium Agrobacterium tumefaciens.
- Transgenic animals are produced by microinjection of foreign DNA into fertilised eggs or by using retrovirus for introducing foreign DNA into early embryonic stages.
- Bioremediation refers to the use of living organisms or their products to decrease pollutants in the environment. Genetically engineered bacteria can clean up pollutants from the environment. The transformed bacteria metabolically break down toxic pollutants into harmless compounds.

Unit Assessment (Review Question)

1) What is the practice of caring for Earth's natural resources so all living things can benefit from them now and in the future?

   a) Preservation b. Conservation c. Development d. Exploitation

2) What is the difference between renewable and non-renewable natural resources?

   a) Renewable resources can be replaced quickly after they are used, while non-renewable resources cannot be replaced at all.

   b) Renewable resources can be used for multiple purposes, while non-renewable resources can only be used for one purpose.

   c) Renewable resources are abundant and cheap, while non-renewable resources are scarce and expensive.

   d) Renewable resources are natural and clean, while non-renewable resources are artificial and polluting.

3) What is the main factor driving biodiversity loss in the world today?

   a) Habitat destruction b. Climate change c. Invasive species

   b) All of the above

4) What is the term for the use of nature by humans in ways that ensure we have resources for the future?

a) Sustainable development c. Ecological footprint

b) Environmental justice d. Green economy

5) What is the term for the situation when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life?

   a) Food security b. Food safety c. Food sovereignty d. Food availability

6) What are the four dimensions of food security?

   a) Availability, accessibility, affordability, and acceptability
   b) Production, consumption, distribution, and utilization
   c) Quantity, quality, diversity, and stability
   d) Supply, demand, price, and trade

7) What is the term for the intake of food in relation to the dietary energy requirements of an individual?

   a) Dietary diversity b. Dietary adequacy c. Dietary quality d. Dietary energy consumption

8) What is the term for the condition in which people lack key micronutrients such as iron, iodine, vitamin A or zinc?

   a) Undernutrition b). Malnutrition c). Hidden hunger d). Stunting

9) What is the term for the production of therapeutic proteins and other drugs through genetic engineering?
   a) Recombinant DNA technology c). Tissue culture technology
   b) Fermentation technology d). Neurotechnology

10) What is the name of the technique that involves splicing a gene from one organism into another to create a new organism?

    a) Cloning b). Transgenesis c). Gene therapy d). CRISPR-Cas9

11) What is the name of the process that allows researchers to grow cells and tissues in the lab for research and medical purposes?

    a) Tissue culture b). Cell division c). Stem cell differentiation d). Organogenesis

12) What is the name of the process that uses microorganisms to produce a wide range of products such as beer, wine, and cheese?

a) Fermentation b). Digestion c). Respiration d). Decomposition

13) What is the term for the use of biotechnology to address environmental challenges, such as developing biodegradable plastics and using microorganisms to clean up contaminated sites?

a) Environmental biotechnology c). Green biotechnology
b) Industrial biotechnology d). Bioenergy

✓ Self-evaluation check list

Put a tick (√) against each of the following tasks which you can perform. If you cannot perform any of these tasks, go back and read the lesson for that particular task.

I can:

S.no	Questions	
1	• Explain the application of biological knowledge in different areas in their environment	☐
2	• Discuss the role of biology in enhancing their livelihood	☐
3	• Value the contribution of biologists and promises biology will have for the society.	☐

Unit: 1, Assignment Questions -1

Instruction: Dear learner, this is a written assignment to be submitted to your tutor and it is part of the formal assessment. Thus, pay significant attention while doing it.

Part I. Discuss on the following questions

1) Discuss the role of biology in the conservation of natural resources
2) Discuss the significance of biology in social, cultural, and economic development in a different context.
3) What are the role of biological knowledge & skills in supporting the community lives (career, health, and wellbeing)

4) Explore Biological applications in your surroundings (agriculture, industry, medicine, waste treatment plants, etc.) and write the report.

5) Discuss the traditional and modern applications of biotechnology in your localities.

6) Interview a biologist and/or search from the internet and come up with a possible list of the promises of biology to the society.

7) What is the difference between antibiotics and vaccines in combating diseases?

8) Outline how insulin is produced by microorganisms.

9) How do you advice the Ethiopian government to include single cell protein technology in food security program.

10) Study a typical solid waste or waste water treatment system and describe the major phases and their purposes.

Answer key for- Unit Assessment (Review Question)

1	B	9	A
2	A	10	B
3	A	11	A
4	A	12	A
5	A	13	A
6	A	14	
7	D	15	
8	C	16	

Answer Key

ACTIVITIES AND SELF-TEST ANSWER KEY

UNIT 1.

The APPLICATIONS OF BIOLOGY IN DAY-TO-DAY LIVES)

Section 1.1 (CONSERVATION OF NATURAL RESOURCES)

Activity 1.1 Essay (Answer)

Ethiopia is endowed with a variety of natural resources, which are crucial for the country's economy and the well-being of its people. However, these resources are facing significant degradation due to various factors.

Main Causes of Natural Resource Degradation

1) **Population Pressure**: The large population exerts a heavy burden on natural resources, leading to overexploitation.
2) **Agricultural Expansion**: To meet the food demand of the growing population, forests are cleared, and grasslands are converted into agricultural fields.
3) **Rapid Urbanization and Resettlement**: Urban sprawl and resettlement programs lead to land degradation.
4) **Climate Change:** Alters precipitation patterns and increases the frequency of droughts, contributing to soil erosion and loss of vegetation.
5) **Environmental Pollution**: Industrial and agricultural pollutants harm the quality of water and soil.

Effects of Natural Resource Degradation

- **Soil Erosion**: Severe soil loss affects agricultural productivity.
- **Biodiversity Decline**: Loss of habitat leads to a decrease in wildlife populations.
- **Water Quality Deterioration**: Pollution and overuse of water resources lead to a decrease in potable water availability.
- **Socio-Economic Problems**: Degradation of resources contributes to poverty and can lead to political instability.

Strategies and Policies Implemented

1) **Soil and Water Conservation Campaigns**: Initiatives to prevent soil erosion and conserve water resources.
2) **Tree Planting Programs**: Efforts to reforest areas and restore ecological balance.

3) **National Conservation Strategy**: A comprehensive plan addressing the sustainable use and management of natural resources.
4) **Wildlife Conservation Strategies**: Management plans for protected areas to preserve biodiversity.
5) **National Biodiversity Strategy and Action Plan**: Aims to conserve ecosystems through effectively managed protected areas and sustainable use of resources outside protected areas.

Conclusion

- While Ethiopia has taken steps to mitigate natural resource degradation, challenges remain. Continued efforts and enhanced strategies are essential to ensure the sustainability of the country's natural resources for future generations.

Self-Test Matching (Answers)

- A – 2, B – 3, C – 1, D – 4

Section review question

1. The main goal of the National Conservation Strategy of Ethiopia is to establish effective systems that ensure the conservation and sustainable use of Ethiopia's biodiversity, provide for the equitable sharing of the costs and benefits arising from it, and contribute to the well-being and security of the nation1.

The four guiding principles of the National Conservation Strategy are:

1) **Conservation of Ecosystems**: Ensuring representative examples of Ethiopia's remaining ecosystems are conserved through a network of effectively managed protected areas.
2) **Sustainable Use Management**: By a set target year, all remaining natural ecosystems outside of the protected areas are under sustainable use management.
3) **Equitable Sharing**: The costs and benefits of biodiversity conservation are equitably shared through a range of partnerships for protected areas management and for sustainable use and marketing of biodiversity.
4) **Agro-Biodiversity Conservation**: The rich agro-biodiversity of Ethiopia is effectively conserved through a mix of in situ and ex situ programs

2. The Biodiversity and Forestry Programme (BFP) of Ethiopia contributes to the conservation and sustainable use of natural resources through various initiatives. Here are some of the ways it contributes:
    1) **Capacity Building**: The BFP supports capacity and skill development for institutions responsible for protected area and forest management, including the use of digital solutions for monitoring and knowledge management.

2) **Community Engagement**: It involves local communities in decision-making processes and restoration activities, recognizing the interdependence between ecosystem conservation and resilient livelihoods.
3) **Legal Income Alternatives**: The program supports smallholder families living adjacent to protected areas by establishing climate-resilient and legal income alternatives, such as sericulture cooperatives.
4) **Ecosystem Services**: The protected areas and natural forests, which cover around 15% of the country's area, are home to many endemic species and provide essential ecosystem services.

Some of the key achievements of the BFP include:

- **Establishment of Sericulture Cooperatives**: These cooperatives have been set up with women who previously relied on illegal wood extraction from national parks, providing them with a sustainable livelihood.
- **Restoration Efforts**: The program has contributed to the restoration and management of forest resources, prevention of soil erosion, and conservation of biodiversity.
- **Income Generation**: It has facilitated income generation for forest user groups and participatory forest management groups.

These efforts align with Ethiopia's broader goals of environmental conservation and sustainable development

<u>Section 1.2 (FOOD AND NUTRITIONAL SECURITY)</u>

<u>Self-Test - True or False (Answers)</u>

1. **False.** Food insecurity is closely related to poverty and can have significant and lasting impacts on individuals, communities, and countries. Poverty can limit access to food, and food insecurity can contribute to a cycle of poverty.
2. **True.** Nutrition security encompasses not only access to sufficient food but also the availability of safe water, adequate sanitation, health care services, and knowledge of good nutritional practices, which together contribute to overall well-being.
3. **False.** While the availability of food is a crucial aspect of food security, it also requires that people have economic and physical access to food, that the food meets their nutritional needs, and that these conditions are stable over time.
4. **True.** Biologists play a key role in ensuring food security by developing high-nutrient crops and new products that address

malnutrition, as well as by establishing climate-resilient agricultural systems and sustainable food production practices.

5. **True.** Microbial fermentation is used in food processing to enhance the sensory, nutritional, and functional attributes of food, which contributes to food preservation, safety, and security by extending shelf life and inhibiting spoilage organisms

Activity 1.2 (answers)

1. The availability of food is influenced by a multitude of factors including agricultural production, climate conditions, political stability, economic resources, and trade policies. Technological advancements and infrastructure also play significant roles in food production and distribution.
2. Food security primarily focuses on the availability and access to sufficient quantities of food, while nutritional security extends this concept to include access to food that is nutritious and safe, and meets the dietary needs of individuals for an active and healthy life.
3. The lack of food and nutritional security can lead to a range of adverse effects such as malnutrition, poor health, reduced mental and physical development in children, increased susceptibility to disease, and diminished productivity and economic growth.
4. Microbial fermentation is a key biological process that supports food security. It not only helps in preserving food and extending its shelf life but also enhances the nutritional value and safety of food products, contributing to a more secure food supply.

Section review question (Answers)

- **Correct answers**: **1- C, 2 – B, 3 – D, 4 – C**

Section 1.3. (CREATING CONSCIOUS CITIZENS AND ENSURING SUSTAINABLE DEVELOPMENT)

Self-Test Answers (True or False)

- **True**. A conscious citizen is indeed someone who values human life and recognizes the interconnectedness of all living things. This awareness extends beyond self-interest and encompasses a sense of responsibility toward the environment and other beings.
- **False**. Biology plays a crucial role in creating conscious citizens by expanding their awareness of social, global, and environmental conditions. Understanding biological processes helps individuals appreciate the delicate balance of ecosystems and the impact of human actions on the planet.
- **True**. Biology empowers conscious citizens to assume personal responsibility by engaging actively, committing to positive actions, and

taking the initiative for a better world. This includes efforts to protect biodiversity, promote sustainable practices, and address health and environmental challenges.

- **True.** The interplay of biology and technology, particularly biotechnology, has become essential for facilitating sustainable development initiatives. Biotechnology allows us to develop innovative solutions for food security, environmental conservation, and healthcare.
- **True.** Conscious citizen biologists indeed contribute to sustainable practices. They create cost-effective technologies that incorporate recycling, reuse components, and reduce waste production. Their strategies aim to sustain a greener Earth and improve food production while minimizing resource consumption.

Activity 1.3. (Answer)

As a student, becoming a conscious global citizen involves understanding our interconnectedness with the world and taking responsibility for positive impact. Here are some steps students like you can take:

1. **Education and Awareness**:
    - **Learn**: Stay informed about global issues, social justice, and environmental challenges. Read books, articles, and attend lectures to expand your knowledge.
    - **Awareness**: Understand the impact of your actions on the planet. Recognize the importance of cultural diversity and respect for all living beings.
2. **Engagement and Action**:
    - **Volunteer**: Participate in community service projects, environmental cleanups, or social initiatives. Engage with local organizations and contribute your time and skills.
    - **Advocacy**: Raise awareness about critical issues. Use social media, organize events, and advocate for positive change.
    - **Sustainable Practices**: Reduce waste, conserve energy, and promote eco-friendly habits. Encourage others to do the same.
3. **Global Perspective**:
    - **Empathy**: Understand different cultures, perspectives, and challenges faced by people worldwide. Develop empathy and compassion.
    - **Collaboration**: Work with international peers, exchange ideas, and collaborate on projects that address global issues.

4. **Biological Awareness**:
    - **Ecosystem Understanding**: Study biology to comprehend ecosystems, biodiversity, and the delicate balance of life on Earth.
    - **Biotechnology**: Explore how biology and technology intersect. Biotechnology can provide solutions for sustainable development.
5. **Personal Responsibility**:
    - **Ethical Choices**: Make ethical decisions in daily life. Consider the impact of your food choices, consumption patterns, and travel habits.
    - **Health and Well-being**: Prioritize physical and mental health. A healthy individual contributes positively to society.
6. **Continuous Learning**:
    - **Stay Curious**: Keep learning and adapting. Attend workshops, conferences, and engage in lifelong learning.

Summary: Being a conscious global citizen involves education, engagement, empathy, and personal responsibility. By combining biology, awareness, and action, students can contribute to a better world.

Section 1. 4 (APPLICATIONS IN BIOTECHNOLOGY)

Activity 1.4 answer

Let us explore the benefits and drawbacks of natural fermentation versus starter cultures in the production of traditional fermented food and beverages, particularly focusing on Ethiopian products. You will also discuss examples and differences in quality and safety.

Natural Fermentation:

- **Process**: Natural fermentation relies on the indigenous microflora present in the raw materials and environment. No specific starter cultures are intentionally added.
- **Benefits**:
    - **Local Diversity**: Natural fermentation preserves the unique microbial diversity of a specific region, contributing to the distinct flavors and characteristics of traditional foods.
    - **Cultural Heritage**: It honors traditional practices and local knowledge.

- **Minimal Equipment**: Requires minimal equipment or specialized knowledge.

- **Drawbacks**:
  - **Inconsistency**: The final product quality can vary significantly due to unpredictable microbial interactions.
  - **Safety Concerns**: Without controlled inoculation, there's a risk of contamination by undesirable microorganisms.
  - **Longer Fermentation Time**: Natural fermentation often takes longer.
- **Examples of Ethiopian Products Using Natural Fermentation**:
  - ***Tella**: Tella* is a traditional Ethiopian beer made from fermented teff or barley. It relies on natural yeast and lactic acid bacteria present in the environment. Quality and safety can vary across different batches and households.
  - ***Shameta***: *Shameta* is another Ethiopian fermented beverage made from barley. It undergoes spontaneous fermentation without specific starter cultures. Its flavor and quality depend on local conditions and practices.
  - ***Siljo***: *Siljo* is a type of traditional Ethiopian condiments. It is spontaneously fermented using wild yeast and lactic acid bacteria found in raw grains/vegetables and utensils. However, consistency and safety can be challenging to achieve.

Starter Cultures:

- **Process**: Starter cultures consist of intentionally selected microorganisms (e.g., bacteria, yeast) added to initiate fermentation.
- **Benefits**:
  - **Consistency**: Starter cultures ensure consistent product quality.
  - **Control**: Allows precise control over fermentation parameters.
  - **Safety**: Reduces the risk of contamination by harmful microbes.
- **Drawbacks**:
  - **Loss of Diversity**: Using specific starter cultures may reduce the natural microbial diversity.
  - **Dependency**: Relies on commercial cultures, which may not align with local traditions.

- **Cost**: Starter cultures can be expensive.

- **Examples of Ethiopian Products Using Starter Cultures**:
  - ***Bulla**: Bulla* is a traditional Ethiopian fermented cereal-based beverage. Some variations of Bulla use specific starter cultures to enhance consistency and safety. These cultures may include lactic acid bacteria and yeast. The resulting Bulla has a more predictable quality.
  - ***Injera**: Injera,* a staple Ethiopian flatbread, is made from *teff* flour. Some modern production methods incorporate commercial starter cultures (e.g., specific strains of lactic acid bacteria) to improve fermentation efficiency and quality. *Injera* made with starter cultures tends to have better texture and uniformity.
  - ***Dabo***: *Dabo* is Ethiopian bread, and its production can benefit from starter cultures. By using specific yeast strains, bakers achieve consistent rising and flavor profiles.

Microorganisms Involved:

- **Natural Fermentation**: Indigenous wild yeast, lactic acid bacteria, and other environmental microbes.
- **Starter Cultures**: Specific strains of lactic acid bacteria (e.g., *Lactococcus lactis*, Lactobacillus spp.) and yeast (e.g., *Saccharomyces cerevisiae*).

Metabolites or Bio-Products:

- **Lactic Acid**: Produced by lactic acid bacteria during fermentation, contributing to acidity and preservation.
- **Ethanol**: Produced by yeast during alcoholic fermentation.
- **Flavor Compounds**: Various volatile compounds (esters, aldehydes) contribute to the unique flavors of each product.

In summary, both natural fermentation and starter cultures play essential roles in Ethiopian traditional foods and beverages. While natural fermentation preserves cultural heritage, starter cultures offer consistency and safety. The choice depends on balancing tradition, quality, and safety considerations.

Activity 1.5. (Answer)

Fermented foods offer a range of health and nutritional benefits. They are known to facilitate digestion, improve gut health, and enhance the bioavailability of nutrients, allowing the body to absorb more of them. Fermentation can also increase the production of certain vitamins, such as B vitamins and vitamin K, and contribute to a healthier intestinal flora. Additionally, fermented foods contain probiotics, which can displace pathogenic bacteria, support immune health, and produce beneficial by-products and metabolites.

In comparison, non-fermented foods may not offer the same level of probiotics or enhanced nutrient absorption. While they can still be nutritious, they lack the unique fermentation process that contributes to the health benefits mentioned above.

In Ethiopia, traditional fermented foods play a significant role in the diet. Some of the common fermented foods or beverages include:

Injera*:* A staple food made from *teff* flour or other grains.

Tella or Farsoo**:** A traditional Ethiopian beer.

Borde: A cereal-based fermented beverage.

Ayib**:** A traditional Ethiopian cottage cheese.

These foods not only contribute to the local cuisine's flavor but also provide various health benefits due to their fermentation process.

<u>Self-Test (answers)</u>

1. Technological applications of biology are vast and have significant impacts on various fields. Here are some key applications and their importance:
   - **Synthetic Biology**: This involves designing and constructing new biological parts, devices, and systems or re-designing existing, natural biological systems for useful purposes. It has applications in producing biofuels, developing new medical treatments, and creating new materials.

- **Biotechnology:** Utilized in the production of therapeutic proteins and drugs through genetic engineering. It is crucial for developing vaccines, antibiotics, and has applications in agriculture to create genetically modified crops that are more resistant to pests and diseases.
- **Genome Editing:** Technologies like CRISPR/Cas9 allow scientists to edit DNA sequences and modify gene function. Its applications range from correcting genetic defects to improving crop resilience.

- **DNA Sequencing:** This technology has revolutionized biology by allowing the decoding of DNA sequences. It is essential for understanding genetic diseases, evolution, and biodiversity.
- **Molecular Cloning:** This is a method for making multiple copies of a specific DNA sequence and is used to create recombinant DNA for various purposes, such as producing proteins or modifying gene functions.
- **Metabolic Engineering:** This involves the optimization of genetic and regulatory processes within cells to increase the cells' production of a certain substance. It is widely used in creating pharmaceuticals and chemicals through microbial fermentation.

  These applications are important because they help address some of the most pressing challenges in healthcare, energy, environment, and food security. They enable us to understand and manipulate biological systems, leading to innovations that can improve the quality of life and the sustainability of our planet.

2. Bioengineering holds significant importance for developing countries like Ethiopia for several reasons:
   - **Healthcare Advancements:** Bioengineering can lead to the development of affordable and accessible healthcare solutions, such as diagnostic tools and treatments that are tailored to local health challenges.

- **Agricultural Improvements:** It can enhance food security through the creation of drought-resistant crops and improved agricultural practices, which is vital for countries reliant on agriculture**.**
- **Environmental Protection:** Bioengineering techniques can be used to address environmental issues, such as water purification and waste management, contributing to sustainable development.
- **Economic Growth:** The bioengineering sector can stimulate economic growth by creating jobs, fostering innovation, and attracting foreign investment.
- **Education and Skill Development:** It promotes education in science and technology, leading to a skilled workforce that can drive the country's development forward.

  Overall, bioengineering can help Ethiopia tackle its unique challenges by providing innovative solutions that are both sustainable and adapted to the local context.

Activity 1.6. (Answer)

Biotechnology can be applied in bio-fortification to enhance the nutrient availability and quality of fruits and grains through several methods:

1) **Agronomic Practices**: Applying nutrients directly to plants or soils to increase their content in the edible parts of plants.
2) **Conventional Breeding**: Selecting and breeding plants with naturally higher levels of essential nutrients.
3) **Transgenic Methods**: Introducing genes into plants that increase the synthesis or accumulation of specific nutrients.

These methods can increase the levels of vitamins, minerals, and other beneficial compounds in crops, making them more nutritious. For example, bio-fortification is undertaken in fruit crops like banana, cassava, beans, tomato, and orange sweet potato.

In Ethiopia, bio-fortified crops have been developed to address micronutrient deficiencies. Examples include:

- **Biofortified Orange Sweet Potatoes**: Rich in vitamin A, helping to combat vitamin A deficiency.
- **Vitamin-A Maize**: Enhanced with vitamin A to improve eyesight and immune function.
- **Zinc Wheat**: Fortified with zinc, which is essential for growth and immune function.
- **Iron and Zinc Lentils:** Enriched with iron and zinc, important for preventing anemia and supporting healthy growth.

These crops are part of efforts to improve diets and address hidden hunger in the country. Biotechnology in bio-fortification thus plays a crucial role in enhancing food security and nutritional status, especially in regions where people rely heavily on staple crops for their daily nutrient intake.

Activity 1.7. (Answers)

Enzymes as biorceptors in biosensors offer several advantages and disadvantages:

Advantages:

- **High Specificity**: Enzymes are highly specific to their substrates, which allows for the selective detection of analytes.
- **Catalytic Activity**: They can amplify the signal by catalyzing reactions, leading to higher sensitivity.
- **Versatility:** Enzymes can be used to detect a wide range of substances, including glucose, cholesterol, and toxins.
- **Fast Response**: Enzymes can provide rapid detection and real-time monitoring of analytes.

Disadvantages:

- **Environmental Sensitivity**: Enzymes can be sensitive to changes in pH, temperature, and other environmental factors, which can affect their stability and activity.
- **Cost:** The extraction and purification of enzymes can be expensive.
- **Shelf Life**: Enzymes may have a limited shelf life, requiring careful storage conditions.

Examples of enzyme-based biosensors include:

- **Glucose Biosensors**: Use glucose oxidase to measure glucose levels in blood, which is crucial for diabetes management.
- **Cholesterol Biosensors**: Utilize cholesterol oxidase to detect cholesterol levels, important for cardiovascular health monitoring.
- **Pesticide Biosensors**: Employ enzymes like organophosphate hydrolase to detect pesticides in food and the environment.

These biosensors have applications in healthcare for monitoring various biomarkers, in environmental monitoring to detect pollutants, and in the food industry to ensure safety and quality.

B). Biosensors

Self-Test (Multiple choice)

1, d; 2, d; 3, b; 4,a; 5, d

Activity 1.8. (Answers)

Forensic scientists use DNA analysis to identify suspects or victims of crimes by comparing DNA samples from the crime scene with those of known individuals or DNA databases. The process typically involves the following steps:

- **Collection:** Biological evidence is collected from the crime scene.
- **Extraction:** DNA is extracted from the samples.
- **Quantification:** The amount of DNA is measured to ensure there's enough for analysis.
- **Amplification:** The DNA is copied using a technique called Polymerase Chain Reaction (PCR).
- **Analysis:** Short Tandem Repeats (STRs) are analyzed to create a DNA profile1.
- **Comparison:** The profile is compared with those of suspects, victims, or database profiles.
- **Interpretation:** Experts interpret the results to determine a match or exclusion.

Advantages:

- **High Specificity**: DNA profiles are highly specific, making them a powerful tool for identifying individuals.
- **Small Sample Size**: Modern techniques can analyze very small amounts of DNA.
- **Database Matching**: DNA databases can link suspects to crimes or identify unknown victims.

Limitations:

- **Contamination Risk**: DNA evidence can be contaminated during collection or analysis, affecting accuracy.
- **Partial Profiles**: Degraded or limited samples may yield partial profiles, complicating interpretation.
- **Ethical Concerns**: DNA databases raise privacy concerns and ethical questions about data storage.

Examples of Cases:

- **The Boston Strangler**: DNA evidence confirmed Albert DeSalvo as the perpetrator nearly 50 years after the crimes.
- **Stephanie Isaacson's Case**: The smallest ever amount of DNA used to solve a case identified the suspect in a 1989 murder.
- **Colin Pitchfork:** The first murder conviction using DNA evidence in the UK for the murders of two schoolgirls.

These cases highlight the transformative impact of DNA analysis in forensic science, both in solving crimes and in exonerating the innocent.

C). Forensic Science

Self-Test Answers (True or False)

- 1. False, 2. True, 3. False, 4. True, 5. False

Activity 1.9. (Answer)

The Role of Biological Knowledge in Forensic Science

Biological knowledge is foundational to forensic science, as it allows for the analysis and interpretation of biological evidence found at crime scenes. This evidence can range from blood, hair, and other bodily fluids to botanical or entomological samples. The application of biology in forensics aids in answering key questions about a crime, such as the identity of the individuals involved the time and cause of death, and the presence of a person at a particular location.

Forensic biology encompasses several sub-disciplines, including forensic genetics, serology, anthropology, botany, entomology, and microbiology. Each of these areas contributes to the legal investigation process by examining different types of biological evidence. For instance, forensic genetics involves DNA profiling to match suspects with evidence, while forensic entomology may use insect life cycles to estimate the time of death.

The evolution of forensic biology has been marked by significant advancements, from early anthropometrical methods to modern DNA fingerprinting techniques. These developments have improved the collection, preservation, and analysis of compromised evidence, making forensic biology a cornerstone of the justice system.

In conclusion, biological knowledge serves as a passport for biological evidence, providing a one-way ticket to crime solving and justice. It is an ever-evolving field that continues to offer novel approaches and methodologies for supporting criminal investigations and ensuring the integrity of the legal process.

(V). Applications in biomining

Self-Test (Answers)

- 1. True, 2. False, 3. True

(Vi). Application in the Environment

Self-Test (Answers)

1. Landfill sites are a common method for solid waste disposal, and they come with their own set of advantages and disadvantages:

Advantages:

- **Ease of Construction**: Landfills can be relatively easy and quick to construct.

- **Cost-Effectiveness**: They offer a cheaper solution for waste disposal compared to other methods.
- **Energy Production**: Landfills can be designed to capture and use methane gas for energy.
- **Job Creation**: They provide employment opportunities in waste management.

Disadvantages:

- **Environmental Impact**: Landfills can lead to groundwater contamination, air pollution, and habitat destruction.
- **Space Requirements**: They require large areas of land, which could be used for other purposes.
- **Long-Term Maintenance**: Closed landfills require monitoring and maintenance for many years.

Biodegradable materials include:

- Wood
- Paper
- Fruit peels
- Eggshells
- Sawdust

These materials decompose naturally over time with the help of microorganisms, contributing to the production of landfill gas and leachate during the decomposition process.

Non-biodegradable materials include:

- Plastic bags
- Styrofoam containers
- Glass bottles
- Aluminum cans

These materials do not decompose easily and can persist in the environment for a very long time, potentially causing ecological harm.

In landfills, biodegradable materials undergo a decomposition process that involves the stabilization of organic matter, leachate production, landfill gas generation, and settlement. Non-biodegradable materials, on the other hand, do not break down and can hinder the decomposition process, leading to increased landfill volume and reduced efficiency in waste management.

2. Composting significantly reduces the volume of solid waste by allowing microorganisms to metabolize organic waste material,

which can decrease its volume by as much as 50 percent. It also improves soil condition by enhancing physical soil structure, making crops less susceptible to pests and diseases, and increasing resilience to disasters like erosion. Compost enriches the soil, promotes healthy microbe growth, and improves water retention and nutrient delivery to plants.

In the composting process:

- **Fungi** break down complex plant polymers, making them essential for degrading recalcitrant compounds and stabilizing organic matter.
- **Bacteria**, including actinomycetes, drive the biochemical degradation of organic matter. They play a crucial role in nitrogen transformation and help in the solubilization of phosphorus and potassium.
- **Actinomycetes** are a type of bacteria that contribute to the decomposition of organic matter, particularly cellulose and lignin, giving compost its earthy smell.

Compost is not considered a fertilizer because it is primarily a soil amendment rather than a direct source of nutrients. While compost does contain nutrients, it releases them slowly over time as it continues to break down, unlike fertilizers, which provide immediate availability for plant uptake. Compost improves soil structure and increases its ability to retain moisture, but it does not necessarily provide the specific balance of nutrients that plants may require from a fertilizer. Therefore, compost is best used to enhance the overall quality of the soil, while fertilizers are used to address specific nutrient deficiencies.

3. Aerobic and anaerobic decomposition are two processes that break down organic matter, but they differ significantly in their mechanisms and outcomes:

Aerobic Decomposition:

- **Oxygen Requirement**: Requires oxygen.

- **Products:** Produces carbon dioxide, water, and heat.
- **Rate:** Generally faster than anaerobic decomposition.
- **Environmental Impact:** Less odor and a more stable end product (compost).
- **Utilization:** The compost produced can be used to enrich soil.

Anaerobic Decomposition:

- **Oxygen Requirement**: Occurs in the absence of oxygen.
- **Products:** Produces methane, carbon dioxide, and other trace gases.
- **Rate**: Slower than aerobic decomposition.
- **Environmental Impact:** Can produce strong odors and contribute to greenhouse gas emissions if methane is not captured.
- **Utilization**: Methane can be captured and used as a renewable energy source.

In modern landfill sites, methane is generated through the anaerobic decomposition of organic waste. Landfill operators capture this methane using a series of wells and a blower/flare system. The collected gas can then be flared, converting methane into carbon dioxide, or it can be used to generate electricity and/or heat, replace fossil fuels in industrial operations, or be upgraded to biomethane standards for use in the energy grid.

The utilization of methane from landfills not only provides a source of renewable energy but also helps to reduce greenhouse gas emissions, as methane is a potent greenhouse gas with a significant impact on global warming. Modern systems aim to optimize methane capture and use, contributing to both environmental protection and energy production.

4. Alternative methods of solid waste disposal beyond landfills and composting include:

- **Incineration**: This method involves burning waste to reduce its volume and potentially generate energy. It is feasible in areas lacking space for landfills, and its efficiency lies in volume reduction and energy recovery. However, it can have negative environmental impacts due to emissions.

- **Recycling:** Separating and processing materials to be reused. Recycling is highly sustainable as it conserves resources and reduces the need for raw materials. Its feasibility depends on the availability of recycling facilities and public participation.
- **Anaerobic Digestion**: This process breaks down organic waste in the absence of oxygen, producing biogas that can be used for energy. It's efficient in waste volume reduction and energy production, and it's sustainable due to the renewable energy output.
- **Mechanical Biological Treatment (MBT):** A combination of mechanical sorting and biological treatment, such as composting or anaerobic digestion, to recover materials and reduce waste. Its sustainability comes from material recovery and energy production, but it requires significant infrastructure.
- **Waste-to-Energy (WtE):** Similar to incineration, WtE uses waste as a fuel to generate electricity or heat. It is efficient in energy recovery and reducing waste volume but has potential environmental concerns related to emissions.
- **Pyrolysis and Gasification:** These thermal processes convert waste into usable fuels. They are efficient in terms of energy recovery and can be sustainable if the energy produced displaces fossil fuels. However, they are complex and require high investment.

The feasibility, efficiency, and sustainability of these methods vary based on local conditions such as waste composition, economic factors, regulatory frameworks, and community acceptance. For instance, incineration may be more feasible in densely populated areas with high land costs, while recycling programs might be more efficient in communities with strong environmental awareness. Sustainability considerations must balance environmental impacts with the benefits of waste reduction and resource recovery. It is crucial to tailor waste management strategies to the specific needs and capabilities of each region to achieve the best outcomes.

5. Householders and local authorities can collaborate to reduce the amount of solid waste through various strategies and initiatives that promote waste reduction, reuse, and recycling:

Strategies for Collaboration:

- **Education and Awareness**: Local authorities can run educational campaigns to inform householders about the importance of waste reduction and proper waste segregation.
- **Incentive Programs**: Implementing incentive-based programs such as pay-as-you-throw or rewards for recycling can encourage householders to reduce waste.
- **Community Composting**: Establishing community composting programs can help divert organic waste from landfills and improve soil health.
- **Infrastructure for Recycling**: Providing accessible recycling bins and facilities can make it easier for householders to recycle.

Initiatives to Promote Waste Reduction:

- **Zero Waste Events:** Encouraging the organization of events where waste is minimized and whatever is generated is recycled or composted.
- **Public-Private Partnerships**: Collaborating with private companies to manage waste more efficiently and introduce innovative waste reduction technologies.
- **Circular Economy Models**: Adopting circular economy principles where products are designed to be reused, repaired, or recycled.
- **Local Ordinances**: Enacting local laws that require or incentivize sustainable waste practices, such as banning single-use plastics.

By working together, householders and local authorities can create a more sustainable approach to waste management that not only reduces the environmental impact but also fosters a sense of community responsibility towards waste reduction and resource conservation. These efforts can lead to a cleaner environment, conservation of resources, and a shift towards a more sustainable future.

Activity 1.10. (Answers)

1. Biofuel production involves converting biomass into liquid fuels like ethanol and biodiesel. Here is a general overview of the process:

Ethanol Production:

- **Biomass Collection**: Crops like corn or sugarcane are harvested for their starch or sugar content.
- **Fermentation**: The biomass is processed to release sugars, which are then fermented by microorganisms such as yeast or bacteria, producing ethanol.
- Distillation: The ethanol is separated from the fermentation mixture through distillation to increase its purity.

Biodiesel Production:

- **Oil Extraction**: Vegetable oils or animal fats are collected as the primary feedstock.
- **Transesterification**: The oils or fats are reacted with an alcohol (usually methanol) in the presence of a catalyst to form biodiesel and glycerol.
- **Purification**: Biodiesel is purified to remove any residual methanol, glycerol, and other impurities.

These biofuels can be used directly in engines or blended with traditional fuels to reduce carbon emissions and reliance on fossil fuels. The production of biofuels is considered sustainable as the feedstocks are renewable and can help in reducing greenhouse gas emissions.

2. Distinguish between biodegradable and non-biodegrdable substances.
   Biodegradable substances are those that can be broken down naturally by microorganisms, such as bacteria and fungi, into simpler, non-toxic substances. These materials typically originate from living organisms and include items like food waste, paper, and wood. They decompose relatively quickly and return to the environment without causing harm.

Non-biodegradable substances, on the other hand, cannot be easily broken down by natural processes. These are often synthetic materials like plastics, metals, and glass. They can persist in the environment for very long periods, potentially causing pollution and harm to ecosystems and wildlife.

Here is a comparison of the two:

Biodegradable Substances:

- Decompose naturally and quickly.
- Broken down by microorganisms.
- Generally non-toxic to the environment.
    - Examples: Food scraps, leaves, paper.

Non-Biodegradable Substances:

- Do not decompose easily or quickly.
- Can accumulate in the environment.
- Often toxic and can cause environmental pollution.
    - Examples: Plastic bags, styrofoam, batteries.

The decomposition process for biodegradable materials contributes to the nutrient cycle and supports environmental health. In contrast, non-biodegradable waste requires careful management to minimize its impact on the planet.

3. Microorganisms play a crucial role in wastewater treatment by breaking down organic pollutants, which can be a source of waterborne diseases and bacterial contamination. Here's how they contribute to the process:
    - **Aerobic Bacteria**: These bacteria use oxygen to degrade pollutants in the water, converting them into energy for growth and reproduction. They are typically used in aerated environments of new treatment plants.
    - **Anaerobic Bacteria**: Common in wastewater treatment, these bacteria reduce sludge volume and produce methane gas, which

can be used as an alternative energy source. They do not require additional oxygen as they get it from their food source.

- **Facultative Microorganisms**: These can switch between aerobic and anaerobic modes depending on the environment, though they prefer aerobic conditions. They help in phosphorus removal from wastewater.

The use of these microorganisms in wastewater treatment helps to treat and purify the water, making it less harmful to the environment. They are essential for maintaining microbial ecological equilibrium in water and sediments, creating favorable conditions for aquatic life, and maintaining a dynamic ecological balance among various organisms. This biological treatment is a key step in ensuring that wastewater is safely recycled back into the environment.

B). Wastewater treatment

<u>Self-Test –Multiple Choice (Answers)</u>

- 1. A, 2. A, 3. A, 4. A

C) Composting

<u>Self-Test – Matching (Answers)</u>

- A-3, B-2, C-4, D-1

B). Biological washing powders

<u>Self-Test –True or False (Answers)</u>

- 1. True, 2. False, 3. True, 4. True, 5.True, 6. True, 7. True, 8. False.

B). The use of Ti plasmid as a vector

<u>Self-Test –True or False (Answers)</u>

- 1. True, 2. False, 3. True, 4. False, 5. True

C). Herbicide resistance

<u>Self-Test True or False (Answers)</u>

- 1. True, 2. True, 3.False, 4. True, 5. False

Viii. Biological warfare

<u>Self-Test Essay (Answers)</u>

1. Biological warfare, also known as germ warfare, is the use of biological toxins or infectious agents such as bacteria, viruses, insects, and fungi with the intent to kill, harm, or incapacitate humans, animals, or plants as an act of war1. These agents can be lethal or non-lethal and may target individuals, groups, or populations. Biological weapons are living organisms or replicating entities, and their use in international armed conflicts is considered a war crime under international law.

   It is important to note that while offensive biological warfare is prohibited, defensive research for protective and peaceful purposes is not banned1. Biological warfare is distinct from other types of weapons of mass destruction, such as nuclear, chemical, and radiological warfare, and it may overlap with chemical warfare when it involves the use of toxins produced by living organisms.

   - The use of biological warfare is not allowed for several compelling reasons:
   - **Unpredictability and Global Threat**: Biological agents can be incredibly resilient and unpredictable, potentially causing widespread and uncontrollable outbreaks.
   - **Non-Discrimination**: Unlike conventional weapons, biological agents cannot distinguish between combatants and non-combatants, posing a significant risk to civilian populations.
   - **Violation of International Law:** The use of biological weapons is considered a war crime under international law, and their deployment is prohibited by numerous treaties.
   - **Ethical Concerns:** The intentional spread of disease is seen as a violation of ethical standards in warfare.
   - **Public Health Risks**: An attack involving biological agents may mimic natural disease outbreaks, complicating public health responses and potentially overwhelming healthcare systems.

- **Security and Verification Challenges**: Ensuring compliance with biological weapons treaties is difficult due to the dual-use nature of many biological research activities, which can have both peaceful and military applications.

These reasons collectively contribute to the global consensus against the use of biological warfare. The potential for catastrophic consequences and the challenges in controlling and containing biological agents make them a particularly dangerous and frowned-upon class of weapons.

Self-Test True or False (Answers)

- Correct Answers: 1. True, 2. C, 3. B

UNIT REVIEW QUESTIONS

- 1. B, 2. A, 3.A, 4. A, 5. A, 6. A, 7. D, 8. A, 9. A, 10. B, 11. B, 12. A, 13. A

UNIT 2

Section 2: Microorganisms

Dear Learner, Welcome to unit two. In the previous unit (**Unit one**), you learned how biology applies to various aspects of life sciences. Biology is the scientific study of living things and their functions. It has many applications in different fields, such as medicine, agriculture, biotechnology, environment, industry, forensic sciences and more. These are some examples of how biology helps us understand and improve the living world around us. Biology is a fascinating and diverse subject that lets us explore the wonders of life.

In this unit (**Unit 2**), you will learn more about the basics of Microbiology, the general features of microorganisms and their roles in the earth's environments, the human use of microorganisms, the microbial causes of infectious diseases, and the taxonomy: organization and classification of microorganisms, and the origin and evolution of microorganisms.

Unit learning Outcomes

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

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

Table of Contents

Unit two study time: (The allotted time is 15 hrs)

LEARNING STRATEGIES

For your successful distance learning process, you can use the following learning strategies wherever they are appropriate to the topics/ subtopics of the lesson: mind mapping, mentally rehearsing, short visits/onsite or microscopic observation , comparing and contrasting, drawing and taking pictures of real microorganisms, creating analogies, paraphrasing, summarizing (outlining and preparing flow chart summaries), taking short notes, underlining or highlighting key points.

SECTION 2.1. WHAT ARE MICROORGANISMS?

INTRODUCTION

☸ **Dear learner**, have you ever seen plants and animals rot when they die? What do you think makes that so? When living organisms die, they undergo a process called decomposition, which means breaking down into smaller and simpler components. This decomposition is caused by the action of microorganisms, such as bacteria and fungi that feed on the dead organic matter and release enzymes that break down the molecules. Therefore, decomposition is important for recycling nutrients and carbon in the ecosystem, and for maintaining the balance of life on Earth.

In this topic, you will explore some of the specific types of microorganisms in more detail. You will learn about their structure, function, reproduction and interactions with other organisms. You will also learn about some of the methods and tools used to study and manipulate microorganisms in the laboratory and in the field.

MINIMUM LEARNING COMPETENCIES

Dear learner, upon successful completion of this section, you will be able to:

- Categorize microorganisms based on their morphology, mode of nutrition, molecular and biochemical analysis.
- Explain the ways of transmission and prevention of pathogenic microorganisms
- Explain the significances of Koch's postulates for the advancement of microbiological techniques.
- Apply the principles of microbiological techniques.
- Discuss the economic importance of microorganisms.

Are microorganisms visible without any aid? If not, what do you need to see them?

Why is microscopic life vital for all life on earth? Where do microorganisms live? And why is it important to study microorganism?

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

Bacteria are relatively simple in structure. They are prokaryotic unicellular organisms with no nuclear membrane, mitochondria, Golgi bodies, or endoplasmic reticulum that reproduce by asexual division.

☞

- The science of **microbiology** is all about microorganisms: what they are, how they work, and what they do.
- **Eubacteria** (biology = definition): Literally means "true bacteria".
- **Microbiology**: is the scientific study of microorganisms
- **Microscopic organisms**: are organisms too small, to be seen with the naked eye, only visible with a microscope.
- **Microbiologist**: is a scientist who studies about microorganisms

What role does microbial diversity play in maintaining ecosystem functions?

Dear learner, the rich diversity of microorganisms is reflected in their profound influence on all aspects of life. Most microorganisms are harmless or indeed beneficial. For example, they are essential to the recycling of nutrients that form the bodies of all organisms that sustain all the metabolic cycles of life. In addition, they produce about 50% of the oxygen gas we breathe and provide other nutrients to many other organisms. Microorganisms survive in, or are purposely put in, many of the foods we eat. Microorganisms and viruses are also in the air we breathe and in the water we drink. Even, some 100 billion microorganisms inhabit in/on our skin and grow in our mouth, ears, nose, throat, and digestive tract. Fortunately, the majority of these microbes, called our natural **microbiota** are actually beneficial in helping us resist diseases, and regulating development and nutrition. When most of us hear the word "bacterium" or "virus", we think infection or disease although such **pathogens** (disease-causing agents) are rare.

☞

Microbes live in most of the world's habitats and are indispensable for normal, balanced life on earth. They play many roles in the functioning of the earth's ecosystems

Self-Test

Choose the correct answer from the given alternatives

1. Which of the following is a correct definition of a microorganism?
   a) A living organism that can only be seen using a microscope
   b) A living organism that is smaller than a millimeter
   c) A non-living organism that can only be seen using a microscope
   d) A non-living organism that is smaller than a millimeter
2. Who was the first person to observe living cells under the microscope in 1675?
   a) Robert Hooke
   b) Anton van Leeuwenhoek
   c) Hans and Zacharias Jansen
   d) Louis Pasteur
3. What is the difference between magnification and resolution in microscopy?
   a) Magnification is the process of making an object appear larger, while resolution is the ability to see objects clearly enough to tell two distinct objects apart.
   b) Magnification is the ability to see objects clearly enough to tell two distinct objects apart, while resolution is the process of making an object appear larger.
   c) Magnification is the process of making an object appear brighter, while resolution is the process of making an object appear sharper.
   d) Magnification is the process of making an object appear sharper, while resolution is the process of making an object appear brighter.
4. What type of microscope uses visible light and two sets of lenses to produce a magnified image?
   a) Simple microscope
   b) Compound microscope
   c) Electron microscope

d) Fluorescence microscope

5. What are some examples of microorganisms that belong to different groups?
   a) Bacteria, fungi, archaea, and protists
   b) Viruses, bacteria, fungi, archaea, plants
   c) Bacteria, fungi, algae, plants, animals, and some amoebae
   d) Viruses, bacteria, fungi, algae, plants, and animals

✓ **Self-evaluation check list**

Put a tick (√) against each of the following tasks, which you can perform. If you cannot perform any of these tasks, go back and read the lesson for that particular task.

I Can:

S.no	Questions	✓ Check
1	• Categorize microorganisms based on their morphology, mode of nutrition, molecular and biochemical analysis.	
2	• Explain the ways of transmission and prevention of pathogenic microorganisms	
3	• Explain the significances of Koch's postulates for the advancement of microbiological techniques.	
4	• Apply the principles of microbiological techniques.	
5	• Discuss the economic importance of microorganisms.	

SECTION 2.2. TYPES OF MICROORGANISMS

INTRODUCTION

☸ **Dear learner,** you welcome to this topic of microorganisms type. This fascinating and important topic can help you understand the diversity and complexity of life on Earth. In the previous topic, you learned about the general characteristics of microorganisms, such as bacteria, fungi, viruses, protozoa and algae.

In this topic, you will explore the types of microorganisms in more detail, domain, and their evolutionally history.

MINIMUM LEARNING COMPETENCIES

Dear learner, after completing this section, you will be able to:

- Explain the domain of microorganisms.
- Group the microorganisms to different taxa.

Can you list the types of microorganisms? What are the bases for microbial classifications?

Dear learner, Most microbes are unicellular and small enough that they require artificial magnification to be seen. However, there are some unicellular microbes that are visible to the naked eye, and some multicellular organisms that are microscopic. An object must measure about 100 micrometers (µm) to be visible without a microscope, but most microorganisms are many times smaller than that.

As you can see from (Figure 2.1) based on evolutionary lines, there are three main kinds of microorganisms, and these are **bacteria, archaea, and eukarea**

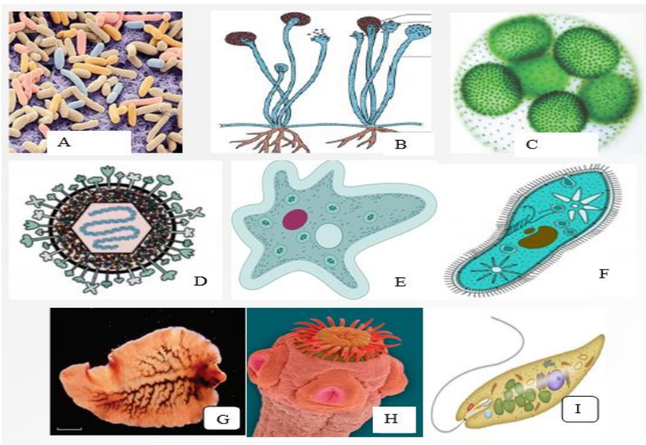


Figure 2.1. Microbial community structure: **Prokaryotes** [Bacteria (A)]; **Eukaryotes** [Fungi (B), Algae (C), Amoeba (E), Paramecium (F), Fluke (G), Tapeworm (H), Flagellates (I)] and **Acellular** [Viruses (D)]

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

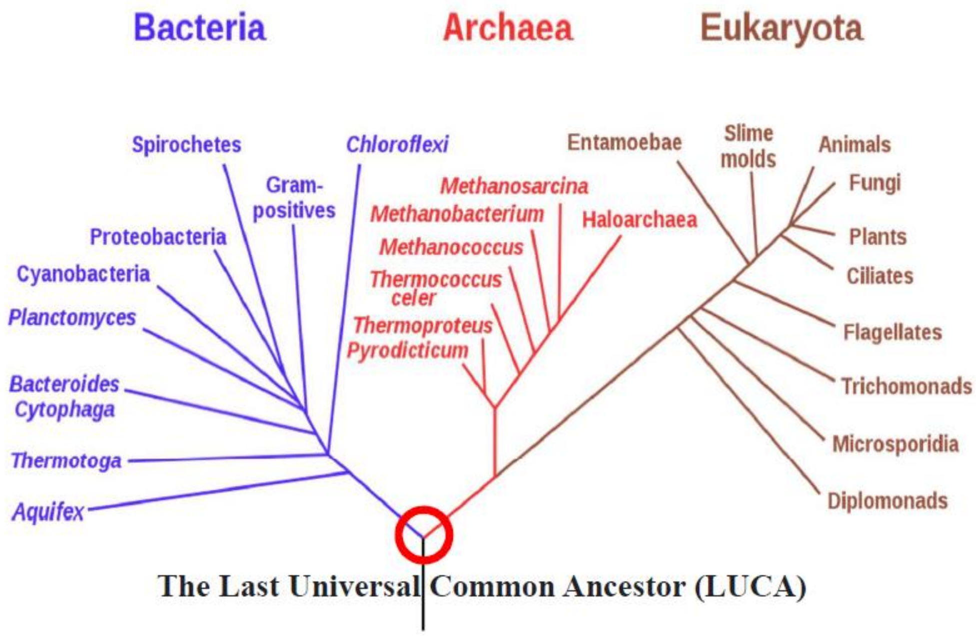


Figure 2. 1. Universal phylogenetic tree life constructed from small subunit of rRNA (SSU= **small subunit**, rRNA) gene sequence analysis.

🛠 Self-test

Choose the correct answer from the given alternatives.

1. Which type of microorganism is most likely to cause food poisoning, pneumonia, and strep throat?

a) Bacteria b). Archaea c).Fungi d). Viruses

2. Which type of microorganism can live in very hot, very cold, very acidic, or very salty environments?

   a) Bacteria b).Archaea c). Fungi d). Viruses

3. Which type of microorganism is unicellular and has a nucleus and other membrane-bound organelles?

   a) Bacteria b). Archaea c). Protozoa d). Algae

4. Which type of microorganism is multicellular and has cell walls made of chitin?

   a) Bacteria b). Archaea c). Fungi d). Algae

5. Which type of microorganism is not a living cell but a particle of genetic material surrounded by a protein coat?

   a) Bacteria b). Archaea c). Fungi d). Viruses

✓ **Self-evaluation check list**

Put a tick (√) against each of the following tasks, which you can perform. If you cannot perform any of these tasks, go back and read the lesson for that particular task.

I Can:

S.no	Questions	✓ Check
1	• Explain the domain of microorganisms.	
2	• Group the microorganisms to different taxa.	

SECTION 2.3. EUBACTERIA

INTRODUCTION

☸ **Dear learner,** I hope you have understood the details of the type of microorganism in the above topic. Now under this topic you will learn about true bacteria, their general characteristics, structure, function, their reproductions, bacterial nutrition, and the disease caused by bacteria.

MINIMUM LEARNING COMPETENCIES

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

- Describe the general features of bacteria.
- Describe the mode of nutrition in bacteria.
- explain the mechanism
- Categorize bacteria based on their shapes.
- Distinguish Gram's positive and Gram's negative bacteria.
- Mention some of the human diseases caused by bacteria.
- Explain the economic importance of bacteria. Apply the principles of microbiological techniques in the studying bacteria.

Dear learner, bacteria are relatively simple in structure. They are prokaryotic unicellular organisms with no nuclear membrane, mitochondria, Golgi bodies, or endoplasmic reticulum that reproduce by asexual division.

☞ **Eubacteria** (biology = definition): Literally means "true bacteria".

Dear learner, what are some common features of Eubacteria? Do they all share the same structure? Let's look some of their general characteristics.

General Characteristics.

- They are omnipresent i.e. present in soil, air and water or everywhere.
- They are unicellular, prokaryotic microorganism = Lack true nucleus (lacking nuclear membrane and nucleolus).
- The cell bears a thick rigid cell wall (Peptidoglycan) outside the plasma membrane.
- They have great variation in the mode of nutrition i.e. may be autotrophic and heterotrophic. In heterotrophism mode of nutrition they may be parasite saprophyte or symbiotic in nature.

- They lack true chlorophyll but few photosynthetic bacteria have a special type of chlorophyll called bacteriochlorophyll.
- They lack mitochondria, Golgi apparatus, plastid and endoplasmic reticulum.
- Both DNA and RNA are present in the bacterial cell.

- **Prokaryotes:** are unicellular organisms that lack a nuclear membrane-enclosed nucleus.
- **Eukaryotes:** are organisms whose cells have a nucleus enclosed within a nuclear envelope.
- **Unicellular:** a unicellular organism has just one cell
- **Multicellular:** a multicellular organism has more than one cell
- **Eubacteria** (biology = definition): Literally means "true

Self-test

1. Why do bacteria have different shapes?
2. What are the chemical compositions of the nucleoid and cytoplasm in a bacterial cell?

Structure of Bacterial Cell

Dear learner, you are now in a position to explain bacterial structure and the relevance of studying microorganisms. In this section you will identify the main internal and external bacterial structures. Now let's look the major bacterial structures.

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

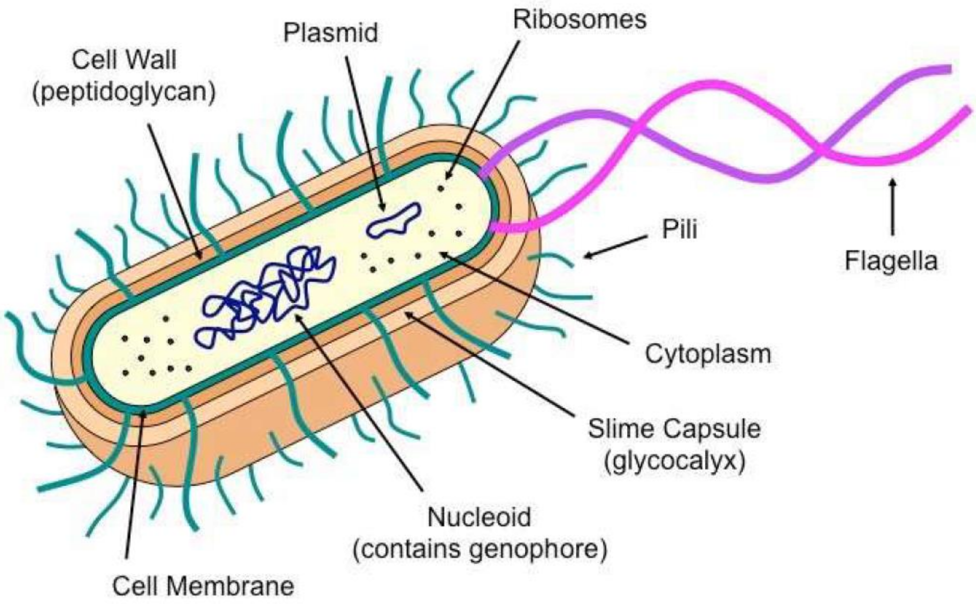
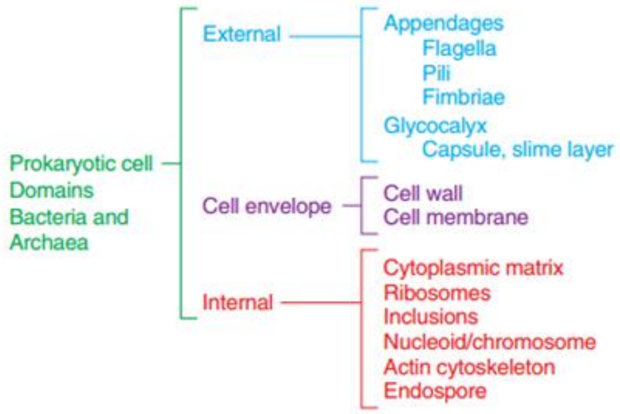


Figure 2.3. Major features of a prokaryotic cell, Bacteria. Source: BioNinja)

The figure above shows the main features of prokaryotic cells, or bacteria. Furthermore, this flowchart (below) is a way to display the general structural plan of a prokaryotic cell in general.



Dear learner,
Which bacterial structure is considered to be internal? Which bacterial structures are classified as external? Compare the difference between eukaryotes and prokaryote cell.

What bacterial structure enables them to move? What structure helps them to attach and reproduce? How can you tell them apart?

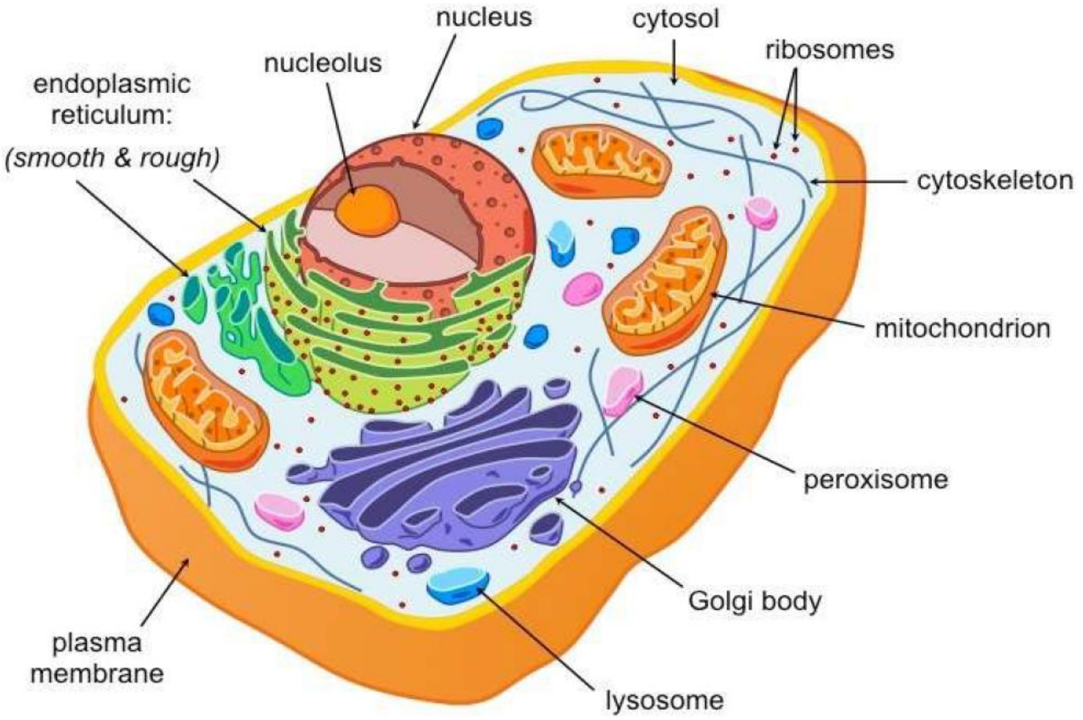


Figure 2.3. Major features of a eukaryotic cell. Source: BioNinja)

Activity 2.1

Please read and write a short note on the structure and function of flagella and pili in bacteria. Additionally, create a table comparing the two structures of cells and submit it to your tutor.

Dear learner, Eukaryotic microbes are an extraordinarily diverse group, including species with a wide range of life cycles, morphological specializations, and nutritional needs. Although more diseases are caused by viruses and bacteria than by microscopic eukaryotes. These eukaryotes are responsible for some diseases of great public health importance.

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

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

Activity 2.2

Read your book and additional materials from websites to compile a list of all eukaryotic microorganisms that may have a cell wall. Then, discuss the type of cell wall, they possess and share your thoughts with your tutor.

Self-Test (Say true if the statement is correct or False if not)

1. Bacteria have a membrane-bound nucleus and other internal structures.
2. Bacteria can have different shapes, such as spheres, rods, spirals, and filaments.
3. Bacteria have a single circular DNA molecule in the cytoplasm called the nucleoid.
4. Bacteria have cell walls made of cellulose.
5. Bacteria can have additional structures such as capsule, flagella, fimbriae, and spores.

Bacterial Shapes

? Do all bacteria have the same shapes? What are the three basic shapes of bacteria? Is there any other more shapes? How do the bacterial cells cluster together?

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

Therefore, bacterial cells can be grouped into the following three main shapes:

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

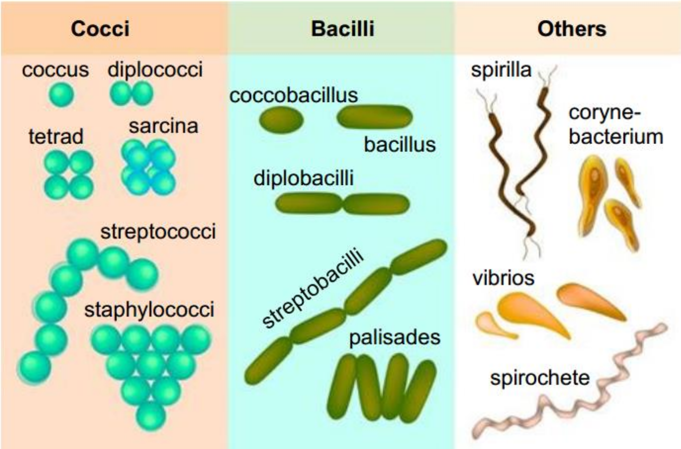


Figure 2.4. Basic bacterial shape and their clustering (Source-

🛠 Self-Test

<u>**Write true if the statement is correct and false if the satment is incorrect**</u>**.**

1. Coccus is a spiral-shaped bacteria.
2. Bacillus is a rod-shaped bacteria.
3. Spirilla are curved or twisted bacteria.
4. Spirochaetes are comma-shaped bacteria.
5. Staphylococci are clusters of spherical bacteria.

Bacterial cell wall

Dear learner, why do you think bacteria are classified as gram positive or gram negative?

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

- **Gram-positive** – Gram-positive bacteria have a distinctive purple appearance when observed under a light microscope following **Gram staining**. This is due to retention of the purple crystal violet stain in the thick peptidoglycan layer of the cell wall. Examples of Gram-positive bacteria include **all staphylococci**, all **streptococci** and some **listeria** species.
- **Gram-negative** – Gram-negative bacteria **lose the crystal violet** stain (and take the color of the red counterstain) in Gram's Method of staining. This is characteristic of bacteria that have a cell wall composed of a thin layer of a particular substance (called **peptidoglycan**).

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

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

Look at the structural labeling below (Figure 2.5) and what do you notice about the difference? Please, list the differences.

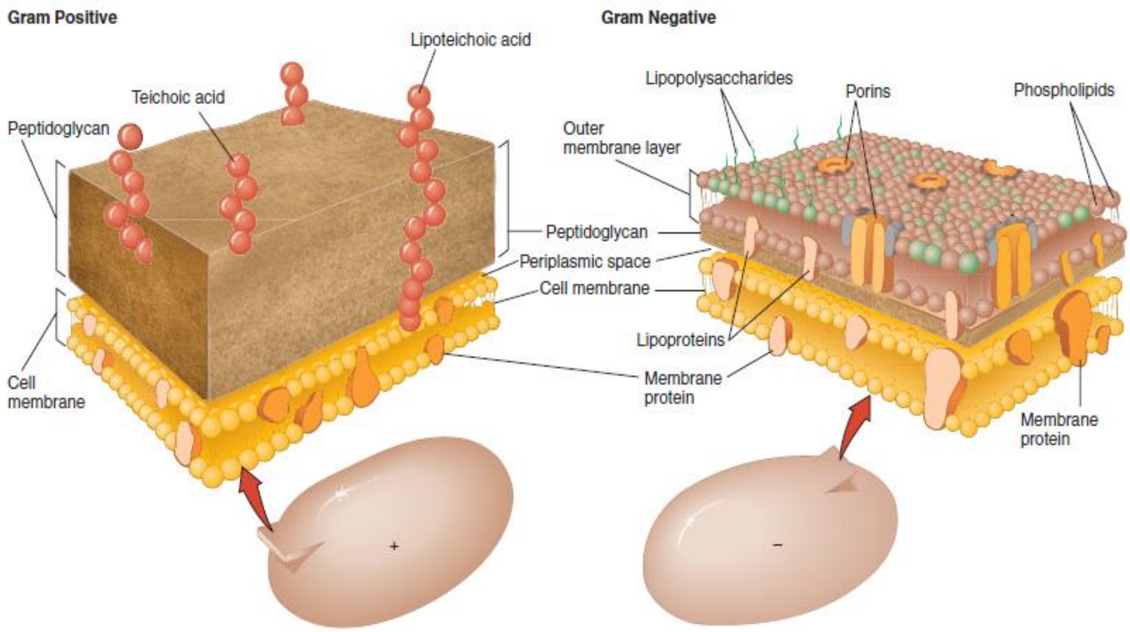


Figure 2.5. Grame positive and gram negative bacterial cell wall

🛠 Self-test

? How does the gram stain procedure differentiate bacteria?

Dear learner, do you know the technique of gram staining? If you do not know, see the procedure below**.**

The Gram staining process includes four basic steps, including:

(1) . Heat fix/ attach the bacteria to the slide,

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

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

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

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

- The staining technique includes simple staining (use single dye) or differential staining (use different dyes) (Figure 2.6)

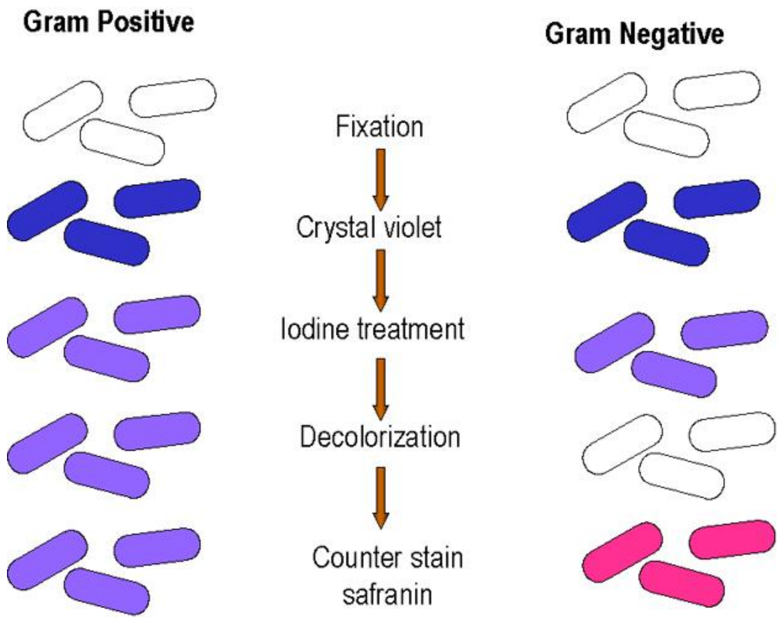


Figure 2.6. Gram staining

KEY-WORDS

- **Gram's staining**: a test for distinguishing bacteria (named after Hans Christian Gram, who developed the technique in 1884)
- **Differential staining:** is a staining procedure that distinguishes organisms based on their staining properties
- **Peptidoglycan:** The rigid layer of the cell walls of Bacteria, a thin sheet composed of N-acetylglucosamine, N-acetylmuramic acid, and a few amino acids.
- **Endotoxin** is the lipopolysaccharide portion of the cell envelope of certain gram-negative bacteria, which is toxin to humans when solubilized.

🛠 Self-Test (match the type of bacteria to their cell wall content)

S.no	A. Gram Positive, B. Gram Negative	
1	Single-layered cell wall	
2	Double-layered cell wall	
3	Teichoic acid	
4	Lipopolysaccharides	
5	Porins	
6	Retains crystal violet dye	
7	Does not retain crystal violet dye	

Nutritional types of bacteria

Dear learner, as part of a group of living things, bacteria need food to survive. But their ways of getting food are not the same. This topic will describe their diverse food strategies.

Bacteria have evolved many mechanisms to acquire the energy and nutrients they need for growth and reproduction. Many are autotrophs, organisms that obtain their carbon from inorganic CO_2. Autotrophs that obtain their energy from sunlight are called **photoautotrophs,** while those that harvest energy from inorganic chemicals are called **chemoautotrophs.** Other bacteria are heterotrophs, organisms that obtain at least some of their carbon from organic molecules like glucose. Heterotrophs that obtain their energy from sunlight are called **photoheterotrophs,** while those that harvest energy from organic molecules are called **chemoheterotrophs**. Sources of energy includes; (1) light energy, and (2) the energy derived from oxidizing organic or inorganic molecules.

Compare and contrast the processes of photosynthesis and chemosynthesis in bacteria. Give examples of bacterial groups that perform each type of metabolism and explain how they obtain energy and carbon from their environment.

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

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

Photolithoautotrophs (often called simply **photoautotrophs**) use light energy and have CO_2 as their carbon source. Photosynthetic bacteria and cyanobacteria employ water as the electron donor and release oxygen. Other photolithoautotrophs, such as the purple and green sulfur bacteria, cannot oxidize water but extract electrons from inorganic donors such as hydrogen, hydrogen sulfde, and elemental sulfur.

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

KEY-WORDS

Autotrophs are organisms that can produce their own food, using materials from inorganic sources.

Heterotrophs are organisms that cannot manufacture their own food by carbon fixation and therefore derive their intake of nutrition from other sources of organic carbon, mainly plant or animal matter.

Phototrophs are organisms that use light as their source of energy to produce complex organic compounds (e.g. carbohydrates) and acquire energy.

Chemotrophs are organisms that obtain energy by the oxidation of electron donors in their environments.

Lithotrophs are a group of organisms using an inorganic substrate to obtain reducing equivalents for use in biosynthesis or energy conservation via aerobic or anaerobic respiration.

Organotrophs are organisms that obtain hydrogen or electrons from organic substrates.

Photoorganoheterotrophs are organisms that use light as their source of energy and organic compounds as their source of carbon.

Chemolithoautotrophs are organisms that use inorganic compounds as their source of energy and carbon dioxide as their source of carbon.

Chemolithoheterotrophs are organisms that use inorganic compounds as their source of energy and organic compounds as their source of carbon.

Chemolithotrophs are organisms that use inorganic compounds as their source of energy and carbon dioxide as their source of carbon.

Chemoorganotrophs are organisms that use organic compounds as their source of energy and carbon.

A)A sexual reproduction

Dear learner, reproduction is a process that never stops for all living things. Bacteria are no exception and can reproduce in different ways. This topic will show you how diverse bacteria can reproduce.

How do you think bacteria reproduce?

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

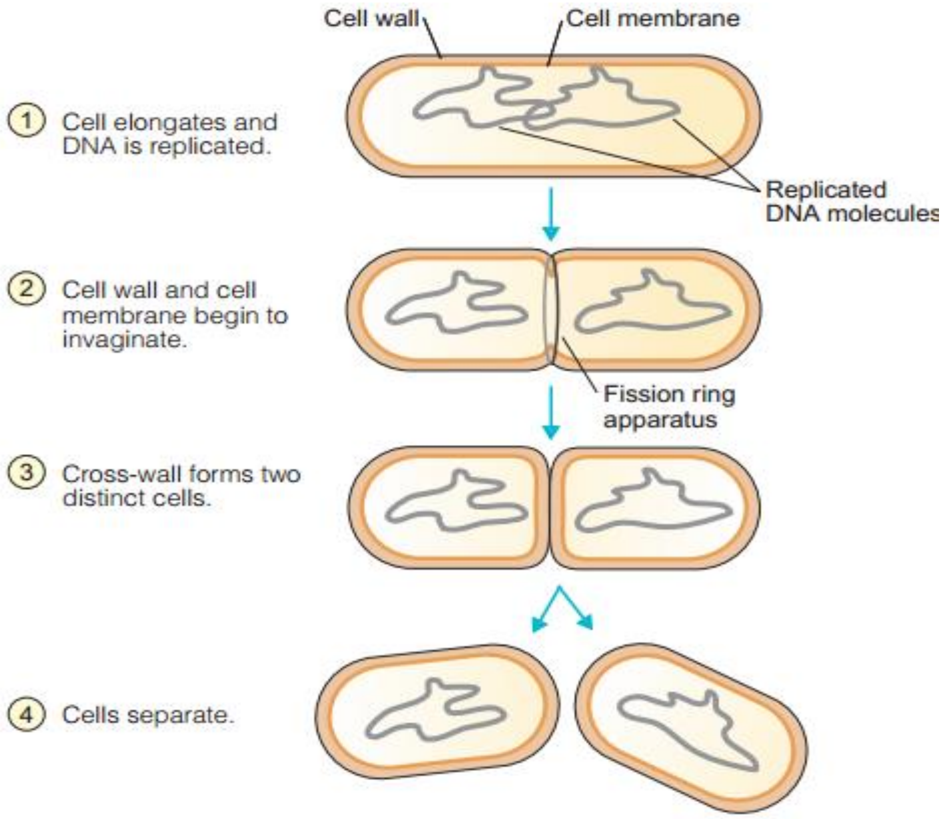


Figure 2.7. **The Process of Binary Fission**

B). Sexual reproduction in bacteria

Dear learner, do you know what a conjugation is? Please, read the following content carefully and write what you understand in your notes.

Bacterial conjugation is a process of horizontal gene transfer, in which bacteria exchange genetic material through direct cell-to-cell contact or a bridge-like connection between two cells. It involves the transfer of a plasmid, a small circular piece of DNA that can replicate independently of the bacterial chromosome, from a donor cell to a recipient cell. In contrast to transformation and transduction, conjugation involves contact between two cells.

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

F genes encode enzymes essential for transferring DNA. Certain F genes encode sex pili, long, hairlike extensions that project from the cell surface. The sex pilus recognizes and binds to the surface of an F cell, forming a cytoplasmic conjugation bridge between the two cells. The F plasmid replicates itself, and DNA is transferred from donor to recipient bacterium through the conjugation bridge. F plasmids may also have other types of genes, including those that determine resistance to antibiotics.

KEY-WORDS

Transformation is the process of transferring free DNA from one bacterium to another.

Transduction is the process by which foreign DNA is introduced into a cell by a virus or viral vector.

Conjugation is a sexual mode of genetic transfer. It involves the transfer of a plasmid or other self-transmissible DNA element and sometimes chromosomal DNA from a donor cell to a recipient cell via direct contact usually mediated by a conjugation pilus or sex pilus.

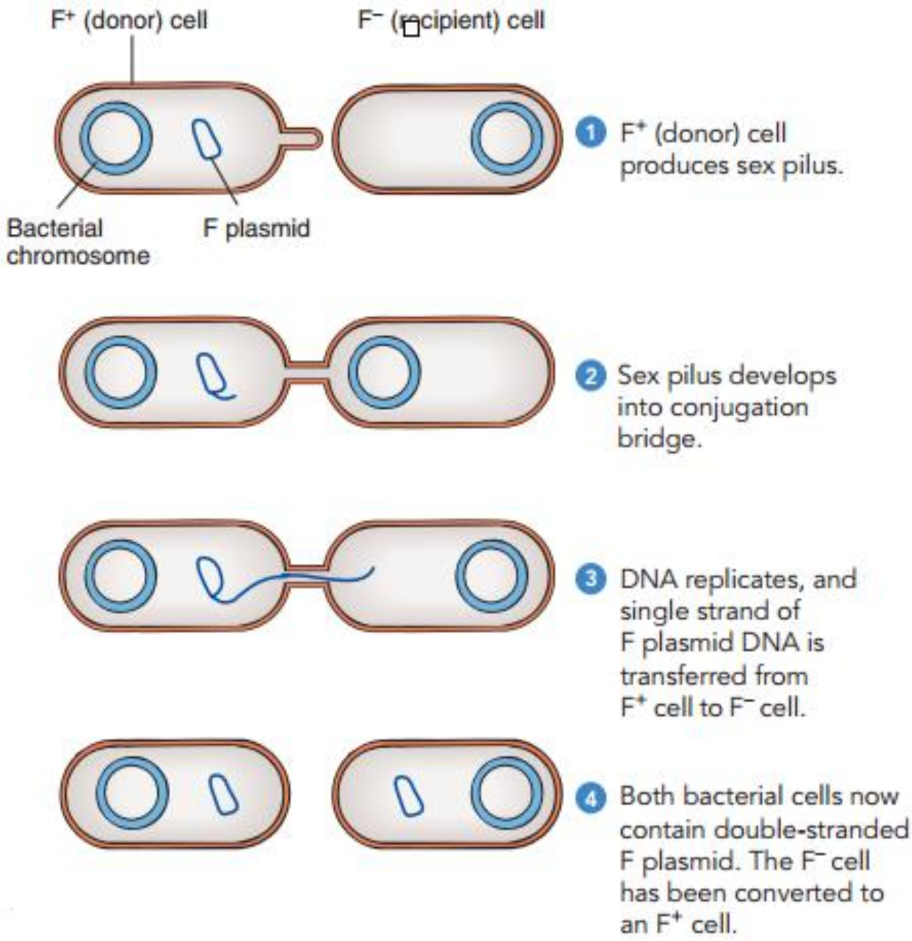


Fig 2.8. Bacterial conjugation

Self-Test

Choose the appropriate answer from the given alternatives.

1. What type of cells can receive plasmid DNA from bacterial conjugation?

   A) F-positive cells B) F-negative cells C) Both A and B D) Neither A nor B

2. What type of DNA is transferred during bacterial conjugation?
   A) Chromosomal DNA B) Plasmid DNA C) Both A and B
   Neither A nor B
3. What is the name of the plasmid that mediates bacterial conjugation?
   A) R-plasmid B) F-plasmid C) B-plasmid D) M-plasmid
4. What is the name of the structure that connects the donor and recipient cells during bacterial conjugation?
   A) Flagellum B) Fimbria C) Pilus D) Capsule

Some common bacterial Diseases

Dear learner, Bacteria can be both helpful and harmful. Some of them cause disease. The summary table below shows the bacteria that are responsible for the disease. Please distinguish these bacteria carefully.

Table 2.3. Common bacterial diseases

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

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

✓ **Self-evaluation check list**

Put a tick (√) against each of the following tasks, which you can perform. If you cannot perform any of these tasks, go back and read the lesson for that particular task.

I Can:

S.no	Questions	✓ Check
1	• Describe the general features of bacteria.	
2	• Describe the mode of nutrition in bacteria.	
3	• explain the mechanism	
4	• Categorize bacteria based on their shapes.	
5	• Distinguish Gram's positive and Gram's negative bacteria.	
6	• Mention some of the human diseases caused by bacteria.	
7	• Explain the economic importance of bacteria. Apply the principles of microbiological techniques in the studying bacteria.	

SECTION 2.4. ARCHAEA BACTERIA

INTRODUCTION

☸ Dear learner, do you know the place called Ertalle? Ertalle is the fascinating world, a place where the Volcano Sea boils in the Afar region. So, you think a living thing would live in such a hot place? You might wonder how any living thing could survive in such a harsh environment, but there is a group of organisms that can do so: the prokaryotic archaea.

In this topic, you will explore about Archae bacteria. You will learn about archae general characteristics, reproduction, and how they contribute to our understanding of life on Earth and beyond.

MINIMUM LEARNING COMPETENCIES

In this section, should be able to**:**

- Give definition of archaea.
- Describe the general features archaea.
- Categorize archaea based on physiological characteristics.
- Explain the beneficial aspects of archaea.

Where are archaea bacteria found? Why archaea-bacterial and other bacterial groups are placed together. What do you think archaea-bacteria unique among the prokaryotes? What are the major differences among the Bacteria, Archaea, and Eukarya? What mechanisms an archaea used to survive in extreme environment?

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

What are the general characteristics of archaea-bacteria?

Dear learner, Archae bacteria has the following general characteristics:

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

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

1. The methanogens are strictly anaerobic organisms, having been isolated from such divergent anaerobic environments as waterlogged soils, lake sediments, marshes, marine sediments, and the gastrointestinal tracts of animals, including humans. As members of the anaerobic food chain, they degrade organic molecules to methane.
2. **Extreme halophiles** grow in highly saline environments such as the Great Salt Lake, the Dead Sea, salt evaporation ponds, and the surfaces of salt-preserved foods. Unlike the methanogens, extreme halophiles are generally obligate aerobes.
3. **Extreme Thermophiles**: The extreme thermophiles (hyperthermophiles) are found near volcanic vents and fissures that release sulfurous gases and other hot vapors. With optimum temperatures usually in excess of 800C, they may be either obligate aerobes, facultative aerobes, or obligate anaerobes.
4. **Thermophilic Extreme Acidophiles**: Members of two genera, Thermoplasma and Picrophilus, are notable for growing in extremely acidic, hot environments.

Keywords

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

Self-Test

Write true if a statement is correct & false if not

1. Archaea are prokaryotic organisms that lack a nucleus and membrane-bound organelles.
2. Archaea have unique lipids in their cell membranes that allow them to survive in extreme environments.
3. Archaea can perform photosynthesis using chlorophyll.
4. Archaea can use different sources of energy and carbon, such as hydrogen, methane, sulfur, or carbon dioxide.

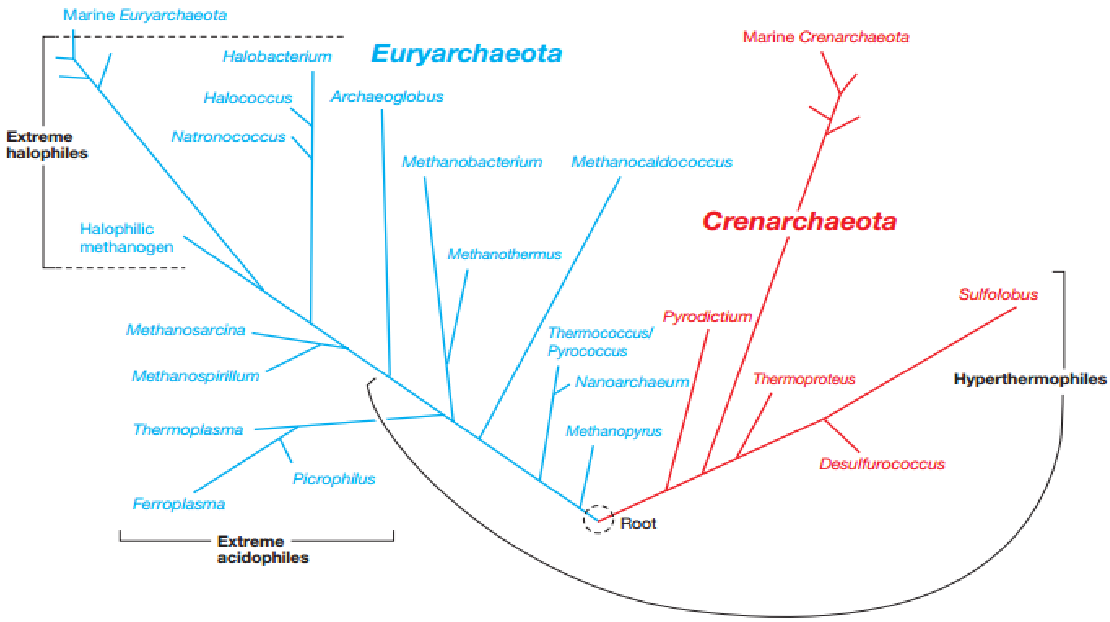


Figure 2.9. Phylogenetic tree of archaea. The tree, based on sequences of 16S ribosomal RNA genes, reveals a major evolutionary split of Archaea into two phyla, the Crenarchaeota and the Euryarchaeota.

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

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

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

What makes halophile, acidophile, and thermophile archaea belong to different branches of the phylogenetic tree?

Different organisms grouped to different branches of the phylogenetic tree because they have different adaptations to their extreme environments and different evolutionary histories.

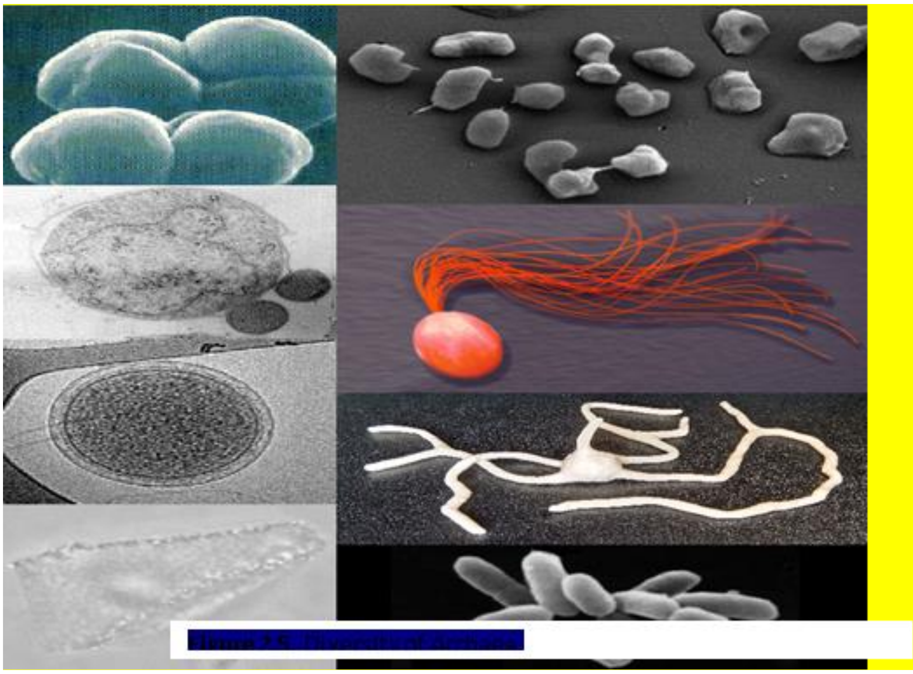


Figure 2.10. Diversity of Archaea.

Beneficial aspects of Archaea

Dear learner, do you believe that archaea have any positive effects on humans? Explain how?

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

These Archaea become the source of enzymes that

1) Are usually added to detergents in order to help it maintain its activity even at higher temperature and pH.

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

Physical factors that affecting microbial growths

Dear learner, the environmental conditions are a major factor that influences the survival and distribution of living things on Earth. Among the living things, archaea are a group of microorganisms that have unique characteristics and adaptations. Therefore, in this lesson, you will learn about the environmental conditions that affect the life of archaea.

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

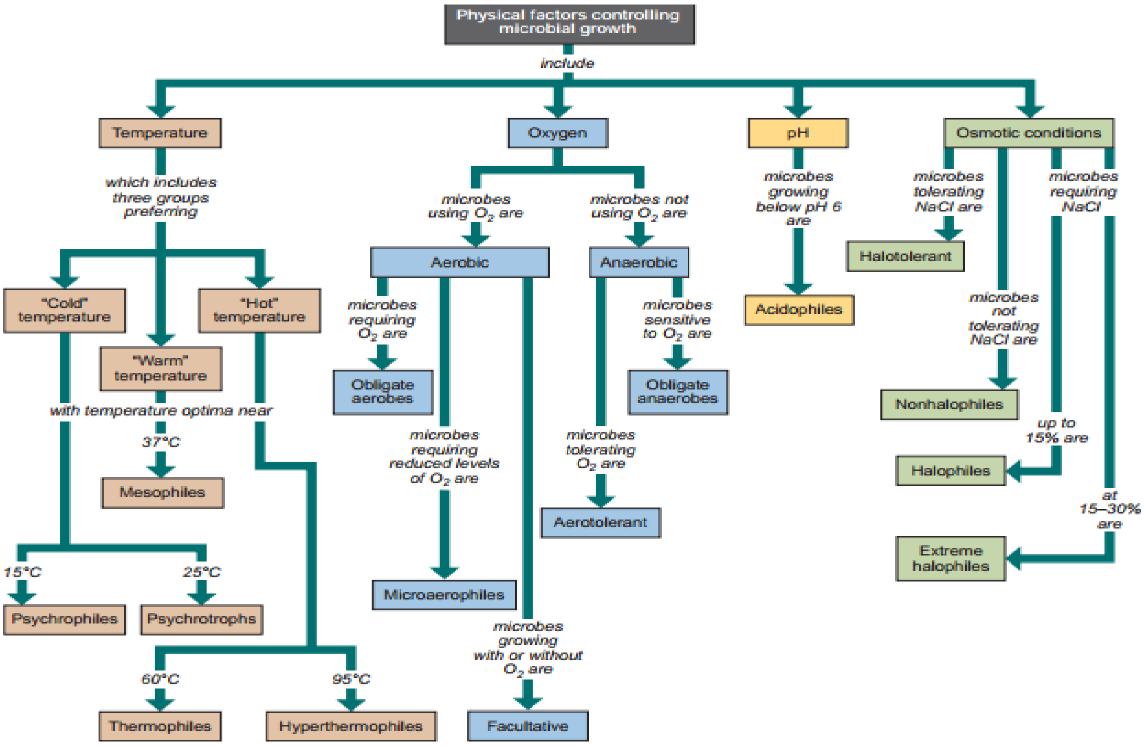


Figure 2.11. Classes of Microbes Based on Physical Factors.

Self-Test

Write true if the statement is correct and false if the statement is incorrect.

1. Water is an essential component for bacterial cells and influences their metabolic activities.
2. All bacteria have the same oxygen requirements for growth.
3. Capnophiles are bacteria that need carbon dioxide for their growth.

✓ **Self-evaluation check list**

Put a tick (√) against each of the following tasks, which you can perform. If you cannot perform any of these tasks, go back and read the lesson for that particular task.

I Can:

S.no	Questions	✓ Check
1	• Give definition of archaea.	
2	• Describe the general features archaea.	
3	• Categorize archaea based on physiological characteristics.	
4	• Explain the beneficial aspects of archaea.	

SECTION 2.5. FUNGI

INTRODUCTION

☸ Dear learner, you have done a great job in learning about bacteria and archaea in the previous topics. Now, we will move on to another fascinating group of microorganisms: fungi. But what is a fungus? Have you ever noticed how bread or Injera (Buddeena) gets moldy when left in a damp place for too long? That is because of fungi growing on them. In this topic, you will learn about the general properties, structures, types, and reproduction of fungi, as well as their benefits and harms to humans and the environment.

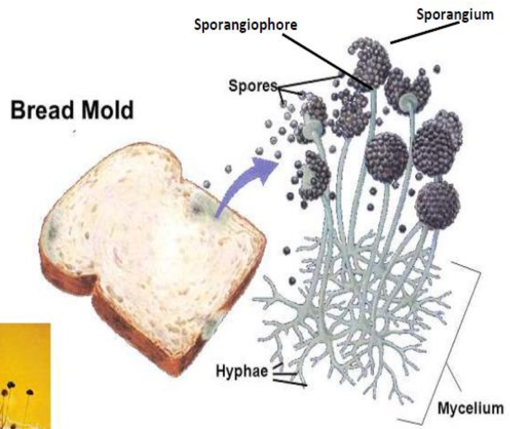
MINIMUM LEARNING COMPETENCIES

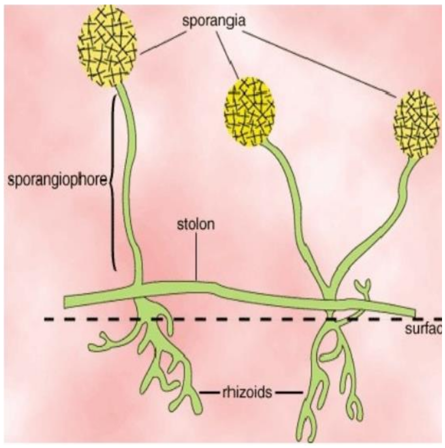
In this section, you will be able to:

- Define fungus.
- Label and describe the hyphal structure.
- Describe how fungi influence human life.
- Explain how fungi grow and reproduce.
- Discuss the ecological importance of fungi.
- Discuss the characteristics of the major groups of fungi.
- Discuss the economic and medical importance of fungi.

What are fungi?

Fungi is a Latin word which means *fungus* = mushroom] to describe eukaryotic organisms that are spore-bearing, have absorptive nutrition,





lack chlorophyll, and reproduce sexually and asexually. Figure 2.13, 14. Different forms of fungi and their structures

Scientists who study fungi are **mycologists** [Greek *mykes,* mushroom, and *logos,* science], and the scientific discipline devoted to fungi is called **mycology.** The study of fungal toxins and their effects is called **mycotoxicology,** and the diseases caused by fungi in animals are known as **mycoses**.

General Characteristics of true Fungi

?	How can we describe the features of fungi?

Dear learner, true fungi have the following general Characteristics

1. **All are eukaryotic**

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

2. Most are filamentous

- Composed of individual microscopic filaments called hyphae, which exhibit apical growth and which branch to form a network of hyphae called a mycelium (Figure 2.8).some have septate hyphae, and the other have nonsepatate (soenocytic hyphae)

3. Some are unicellular

- e.g. yeasts. (Figure 2.8)

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

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

5. Many reproduce both sexually and asexually

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

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

- Although the Oomycota and some yeasts possess diploid nuclei.

7. All are achlorophyllous

- They lack chlorophyll pigments and are incapable of photosynthesis.

8. All are chemoheterotrophic (chemo-organotrophic)

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

9. Possess characteristic range of storage compounds

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

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

> What are the ecological roles of different kinds of fungi? Which fungal features permit some fungal species and not others to be pathogenic on humans?

Fungi play a crucial role in the balance of the ecosystems. They colonize most habitats on earth, preferring dark, moist conditions. In these environments, fungi play a major role as decomposers and recyclers and making it possible for members of the other kingdoms to be supplied with nutrients and to live. Inevitably, the food web would be incomplete without organisms that decompose organic matter. Apart from this benefit (**Figure 2.9**) fungi cause disease and immense economic losses (**Figure 2.10**). Their harmful activities as saprotrophs include damage to timber, fuel, food, and manufactured goods. As parasites, they cause heavy crop losses and diseases of humans and domestic animals. The beneficial activities of yeasts and other fungi, however, are also of great economic significance. They have long been exploited as food, as a component in the processing of food, and as biological mechanisms in the process of alcohol production and traditional fermentation (**Figure 2.9**). For example, their role in Enjera (Buddeena), Tej (Daadhii), Tella (Farsoo), and Kocho fermentation. In the present century, as the fermentation industry has developed, the applications of fungi have produced an increasing range of valuable products, including antibiotics and other drugs of great

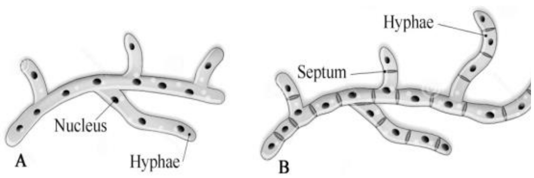


Fig: (A) Aseptate (coenocytic hyphae) and (B) Septate hyphae pharmaceutical value, agricultural fungicides and plant growth regulators, vitamins and enzymes.

?	Which are some examples of fungi that are involved in human food preparation? How do they contribute to different food items? Can you name another type of microorganism that is also used for food production?

Recently, with the advent of genetic manipulation, fungi are being used to produce hormones and proteins, which is available only from mammals. The utilization of fungi to benefit humans can be regarded as a part of biotechnology.

?	Fungi have applications in biotechnology. Can you name some of them? How do fungi spoil food? How do you define a fungal disease? Give five examples of fungal diseases that affect plants or animals. What are the major human diseases caused by fungi?

Self-Test

Fill the blank spaces

1. Fungi are __________ organisms that build their cell walls from the polysaccharide chitin and are classified as heterotrophs among the living organisms

2. A typical fungus consists of a mass of branched, tubular filaments enclosed by a rigid cell wall. The filaments, called hyphae, branch repeatedly into a complicated, radially expanding network called the __________, which makes up the thallus, or undifferentiated body, of the typical fungus

Self-test

Essay type.

1. Do fungi have a benefit for humans? If yes, list their importance.
2. Where do different fungal groups grow in nature? How do different fungi get their nutrients?
3. Discuss the significance of fungi in nutrient cycling and soil health. How do their saprophytic activities contribute to ecosystem sustainability?
4. Analyze the mechanisms by which pathogenic fungi infect host organisms. What are the implications of fungal diseases for agriculture and human health?
5. How do different kinds of fungi, including lichenized fungi, reproduce asexually? Sexually?

Classification of Fungi

Dear learner, Classification groups living organisms according to how similar they are. Fungi are one group of the eukaryotic kingdom. This topic will also teach you about the different methods of classifying fungi.

Morphologically fungi can be categorized into: **yeasts, molds, and dimorphic fungi**. Besides to this, true fungi can be classified into **six groups**:

- Chytridomycota. Zoospore producing fungi. E.g. allomyces & water molds
- Glomeromycota. E.g. mycorrhizal fungi.
- Zygomycota. Sporangial fungi, E.g. rhizopus and mucor
- Ascomycota. Ascospore producing fungi. E.g. *Saccharomyces cerviciae*
- Basidomycota. Basidia producing fungi. E.g. rusts & smuts
- Deutromycota. Fungi imperfect. E.g. penicilium and aspergillus

🛠 Self-Test

Write True if the statement is correct or False if it not

1. Ascomycota are fungi that produce asexual spores called ascospores.
2. Basidiomycota are fungi that produce club-shaped structures called basidia.

Reproduction in fungi

Dear learner, reproduction is a characteristic of living things. Fungi are a group of living things. This means they have the ability to reproduce like other living things. In this topic, you will learn more about the reproduction of fungi.

How do fungi reproduce?

Fungi can reproduce asexually by fragmentation, budding, or producing spores, or sexually with homothallic or heterothallic mycelia. Sporulation is the process of spore formation. It usually occurs in structures called fruiting bodies, which represent the part of a fungus in which spores are formed and from which they are released. These structures may be asexual and invisible to the naked eye, or sexual structures, such as the macroscopic mushrooms.

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

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

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

Figure 2. 14. Fungal fruiting bodies

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

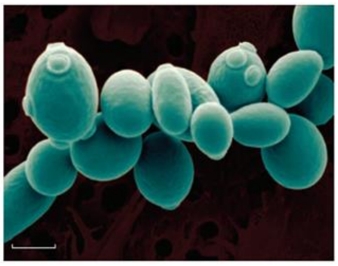


Fig 2.15. Budding in yeast

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

Self-Test

Fill the blank Space by the appropriate answers

1. Fungi can reproduce by _________, or _________ methods.
2. Asexual reproduction in fungi involves the production of _________ that can germinate into new individuals.
3. Sexual reproduction in fungi involves the fusion of _________ from two compatible mating types.
4. Vegetative reproduction in fungi involves the growth of _________ or _________ from a part of the parent fungus.

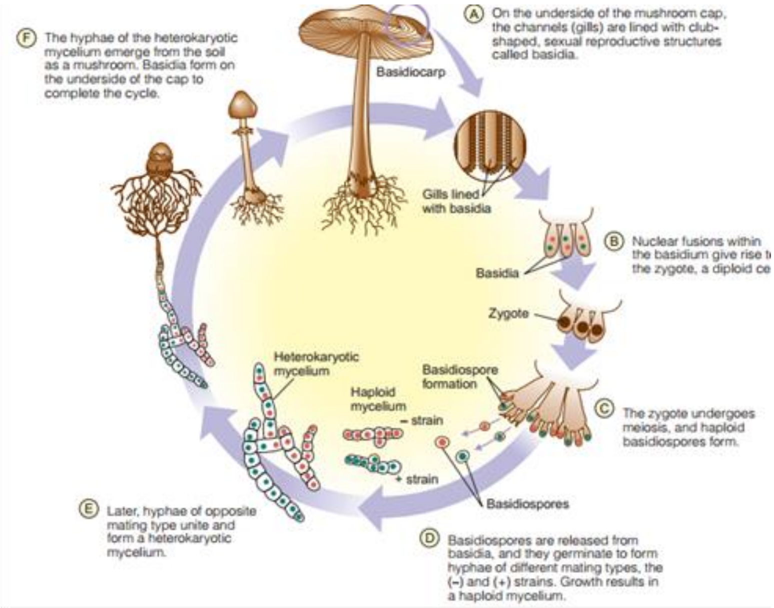


Figure 2 .16 The Sexual Reproduction Cycle of a Typical Basidiomycete.

Economic importance of fungi

Dear learner, fungi are among the economic important microrganisms. They have both beneficial and harnmful aspects. First let's look the beneficial effects.

Beneficial aspects of fungi

1. Fungi exist either as saprobes or parasites. Their preeminent ability to break down complex organic substrates of almost every type is an important and

essential activity in the recycling of carbon and other elements in the cycle of life.

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

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

4. Fungi also play a major role in the preparation of some cheeses, soy sauce, and sufu, Enjera, Tela(Farsoo), Tej(Dadhii), bulla, ETC. (Figure 2.17); and in the commercial production of many organic acids (citric, gallic) and certain drugs (ergometrine, cortisone).

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

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

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

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

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

Figure 2.17. Some Ethiopian traditional fermented products (A= staple foods; B, beverages; and C, condiments)

Harmful aspects of Fungi

Dear learner, some fungi are beneficial for humans and the environment, but others are detrimental, as indicated above. Here are some of the harmful effects caused by fungi.

1. Fungi are the major cause of plant diseases. Plants are particularly vulnerable to fungal diseases because fungi can invade leaves through their

stomates. Over 5,000 species attack economically valuable crops, garden plants, and many wild plants. Fungi also cause many diseases of animals and humans.

2. Molds can cause deterioration of fabrics, leather, electrical insulation and other manufactured goods. Extensive losses may follow failure to protect material from ravages of fungi in warm humid climates.

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

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

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

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

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

5. Superficial Fungal infections

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

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

- Tinea corporis (ringworm): Microsporum canis and Trichophyton mentagrophytes. Affects hairless skin.
- Tinea pedis (athlete's foot): T. rubrum, T. mentagrophytes, and Epidermophyton floccosum. Affects mainly the lower legs.
- Tinea capitis: T. tonsurans and M. canis. the scalp, eyebrows, and eyelashes
- Tinea barbae: T. rubrum and T. mentagrophytes. Beard ringworm.
- Tinea unguium (also known as **onychomycosis**).: T. rubrum, T. mentagrophytes, and E. floccosum. Affect the nails

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

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

Tinea capitis caused by *Microsporum canis* Onychomycosis caused by *Trichophyton rubrum*

Figure 2.18. Fungal disease affecting human and plants

Table 2. 4. Summry of some fungal diseases

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

Self-Test

(Fill the blank space with appropriate answers**)**

1. Fungi produce substances that help to cure diseases caused by pathogenic microorganisms. These substances are called __________.

2. Fungi help to maintain soil fertility by decomposing organic matter and releasing __________.
3. Fungi are consumed as food by humans and animals. Some examples of edible fungi are __________ and __________.
4. Fungi are the basis of many industries such as brewing, baking, cheese-making, etc. They use fungi such as __________ and __________.
5. Fungi can also cause harm to humans and plants by causing diseases and spoilage. Some examples of fungal diseases are __________ and __________.

✓ **Self-evaluation check list**

Put a tick (√) against each of the following tasks, which you can perform. If you cannot perform any of these tasks, go back and read the lesson for that particular task.

I Can:

S.no	**Questions**	✓ **Check**
1	• Define fungus.	
2	• Label and describe the hyphal structure.	
3	• Describe how fungi influence human life.	
4	• Discuss the ecological importance of fungi.	
5	• Discuss the characteristics of the major groups of fungi.	
6	• Discuss the economic and medical importance of fungi.	
7	• Explain how fungi grow and reproduce.	

SECTION 2.6. PROTOZOA

INTRODUCTION

☸ Dear learner, you have done a great job in learning about bacteria, archaea and fungi in the previous topics. Now, we will move on to another fascinating group of microorganisms: protozoa. But what is a protozoa? In this topic, you will learn about the general properties, structures, types, and reproduction of protozoa, as well as their benefits and harms to humans and the environment.

MINIMUM LEARNING COMPETENCIES

- Describe the general features of protozoa.
- Describe the structures of amoeba, euglena, and paramecium.
- Explain how protozoans get nutrition.
- Describe the modes of reproduction in protozoa.
- Describe the process of conjugation in protozoa.
- List the common diseases caused by protozoans.
- Explain the ways of transmission of protozoan diseases.
- Explain the economic importance of on human protozoans.
- Analyze the health impacts of different protozoan diseases.

In this section, you will be able to:

Protozoa (singular: **protozoan**) are unicellular eukaryotic microscopic animals which may be free-living or parasitic, and/or get their energy from the organic carbon. Some of them are free-living and the others are parasitic in nature. Amebae move by using extensions of their cytoplasm called *pseudopods* (false feet).

☞ All protozoa contain a "true," or membrane-bound, nucleus and membrane-bounded organelles within their cytoplasm. Protozoa contain flagella, cilia, or pseudopodia means they are motile.

Explain how protozoans are identified and classified. Explain some biological properties of parasites, and list some common protozoan pathogens. How do Protista differ from monera and from other eukaryotes? What are some habitats of protozoa?

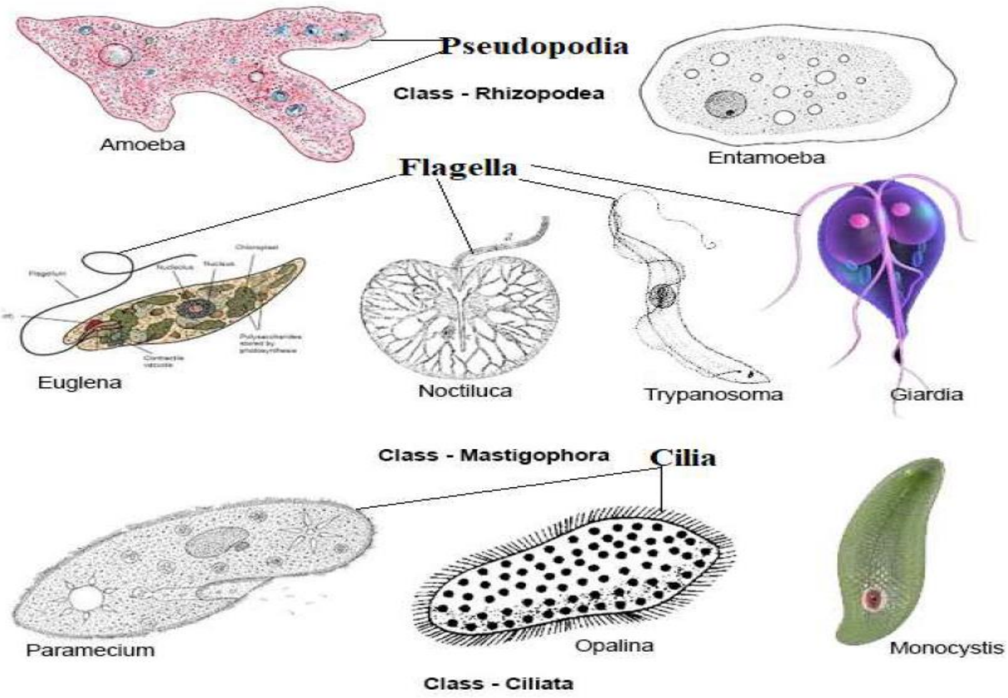


Figure 2.11. Common protozoa

What are the general characteristics of protozoan?

Dear learner, Listed below are some of the general characteristics of protozoan:

- Unicellular microorganisms that lacks cell wall.
- They are free living or parasitic.
- Aerobic.
- They have true nucleus.
- They are eukaryotic cells.
- Mostly microscopic, although some are large enough to be seen with the unaided eye (Figure 2.19).
- Locomotion by pseudopodia, flagella, cilia, and direct cell movements; some sessile.
- Nutrition of all types: autotrophic (manufacturing own nutrients by photosynthesis), heterotrophic (depending on other plants or animals

for food), saprozoic (using nutrients dissolved in the surrounding medium)

- Aquatic or terrestrial habitat; free-living or symbiotic mode of life
- Reproduction asexually by fission, budding, and cysts and sexually by conjugation or by syngamy (union of male and female gametes to form a zygote).

Dear learner, the table below describes the protozoan group and their characteristics. So, read it carefully and identify their characteristics.

Table 2.5. Classification of protozoa

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

Self-Test

Choose the correct answer from the give alternatives.

1. Which of the following is a term for the resting form of a protozoan that resists harsh conditions?
   A) Trophozoite B) Cyst C) Sporozoite D) Gametocyte
2. Which of the following is a type of locomotor organelle found in protozoa?
   A). Flagella B). Pili C). Fimbriae D). Capsules
3. Which of the following is a kingdom that includes protozoa?

   A) Animalia B) Fungi C) Protista D) Monera

4. Which of the following is a mode of nutrition for protozoa?

A) Photosynthesis B) Phagocytosis C) Chemotrophy D) Nitrogen fixation

Activity 2.3

Read the module and any additional materials, then explain your understanding to the tutor. Finally, summarize the written material on the protests, that they are small and can cause disease. However, aren't they considered bacteria, which also possess these characteristics?

Reproduction in protozoa

How do protozoa reproduce?

Dear learner, most protozoa are asexual reproduce in one of three ways. These are:

- **Fission**: Fission occurs when a cell divides evenly to form two new cells (Figure 2.20).
- **Budding**: Budding occurs when a cell divides unevenly.
- **Multiple fission** (schizogony): Multiple fission is when the nucleus of the cell divides multiple times before the rest of the cell divides. Forms around each nucleus when the nucleus divides then each nuclei separates into a daughter cell.

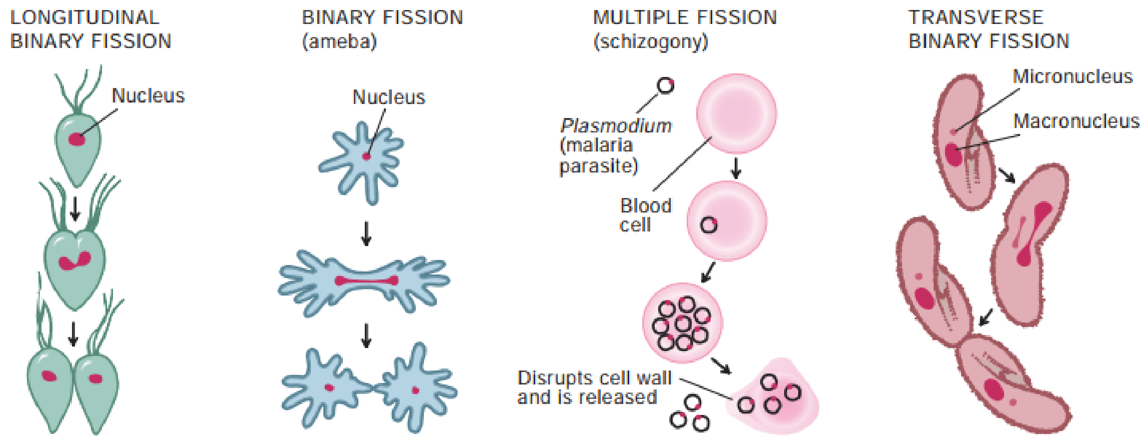


Figure 2.20 Asexual reproduction in protozoa

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

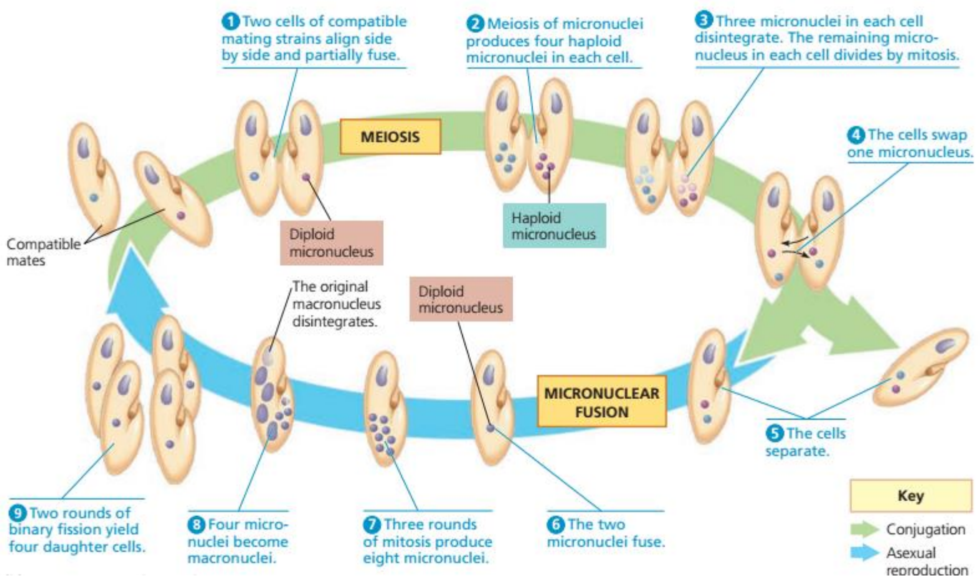


Figure 2.21. Conjugation in Paramecium

Seilf-Test

Write true is a statement is correct or false if a statement is incorrect.

1. Protozoa can reproduce by fission, schizogony, or budding.
2. Protozoa can produce spores that are resistant to harsh conditions.
3. Protozoa can only reproduce asexually.
4. Some protozoa can have more than one nucleus in a cell. (True, False)
5. All protozoa can perform photosynthesis.

Nutrition in Protozoans

How do protozoan get their food?

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

• **Absorption:** Food is absorbed across the protist's plasma membrane.

• **Ingestion:** Cilia outside the protist create a wave-like motion to move food into a mouth-like opening in the protist called a *cytosome*. An example is the paramecium.

• **Engulf:** Pseudopods (meaning "false feet") on the protist engulf food, then pull it into the cell using a process called *phagocytosis*. An example of this type of protist is the amoeba.

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

Self-Test

Fill the blank space with appropriate answers

1. Protozoa that absorb dissolved organic matter from their surroundings are called __________.
2. Protozoa that live in or on other organisms and derive nutrients from them are called __________.

Self-test

1. What are the types of nuclei and vacuoles in protozoa?

Common diseases caused by protozoa

Dear learner, did you know that protozoa cause disease on human or other animals?

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

Table 2.1. Major protozoal parasites of human and other organisms

Disease	Some Representative Etiological Agents	Geographical Localization	Clinical Features
Malaria	*Plasmodium falciparum*, *P. vivax*	Over 100 countries in the tropic and subtropics	Fever, shivering, cough, respiratory distress, pain in the joints, headache, watery diarrhea, vomiting, convulsions, severe anemia
African trypanosomiasis	*Trypanosoma brucei*	36 countries in sub-Sahara Africa	Initial haemolytic phase (fever, joint pains followed by neurological disorder, somnolence)
Chagas disease	*Trypanosoma cruzi*	From northern Mexico to South Argentina	Acute phase (fever and splenomegaly) Chronic phase (irreversible damage to heart, esophagus and colon)
Leishmaniasis	*Leishmania donovani*, *L. major*, *L. mexicana*, *L. braziliensis*	Over 88 countries in tropic and subtropics	Skin ulcers, mucocutaneous complications and visceral diseases (hepatosplenomegaly)
Toxoplasmosis	*Toxoplasma gondii*	Worldwide	Blindness and mental retardation can result in congenitally infected children. Immunosuppressed patients can present more severe symptoms: splenomegaly, polymyositis, dermatomyositis, chorioretinitis, myocarditis, pneumonitis, hepatitis, encephalitis, and multisystem organ failure.
Trichomoniasis	*Trichomonas vaginalis*	Worldwide	Vaginal discharge, odor and edema or erythema

Intestinal protozoan	*Giardia lamblia*, *Entamoeba histolytica*, *Cryptosporidium parvum*, *Cyclospora cayetanensis*	Worldwide	Hematuria, anemia, impaired growth. Renal, hepatic and spleen failure

Mucocutaneous leishmaniasis *Cutaneous leishmaniasis* Trypanosoma infected cow

Figure 2.12a. Leishmaniasis and Trypanosomiasis

Self-test

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

✓ **Self-evaluation check list**

Put a tick (√) against each of the following tasks, which you can perform. If you cannot perform any of these tasks, go back and read the lesson for that particular task.

I Can:

S.no	Questions	✓ Check
1	• Describe the general features of protozoa.	

2	• Describe the structures of amoeba, euglena, and paramecium.	
3	• Explain how protozoans get nutrition.	
	• Explain the economic importance of on human protozoans.	
	• Analyze the health impacts of different protozoan diseases.	
4	• Describe the modes of reproduction in protozoa.	
5	• Describe the process of conjugation in protozoa.	
6	• List the common diseases caused by protozoans.	
7	• Explain the ways of transmission of protozoan diseases.	

SECTION 2.7. VIRUSES

INTRODUCTION

☸ **Dear learner**, you have done a great job in learning about bacteria, archaea and fungi in the previous topics. Now, we will move on to another fascinating group of microorganisms: Virus. But what is a Virus? In this topic, you will learn about the general properties, structures, types, and reproduction of virus, as well as their benefits and harms to humans and the environment.

MINIMUM LEARNING COMPETENCIES

In this section, you will be able to:

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

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

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

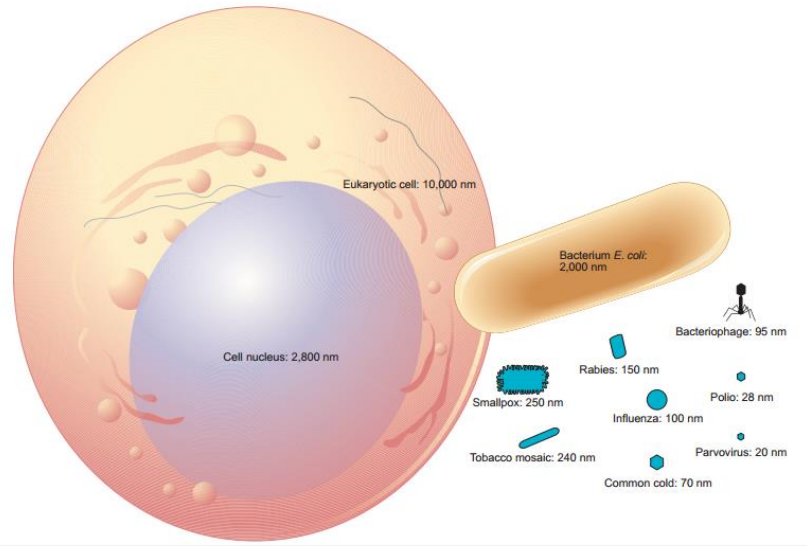


Figure 2.23. Variations in size among eukaryotic cells, prokaryotic cells and viruses

What are the general characteristics of viruses?

Dear learner, if you remember your elementary school lessons, viruses are an obligate intracellular parasites that have their own characteristics that set them apart from other organisms. Therefore, the following are the general characteristics of viruses.

General characteristics of viruses

- Viruses have an inner core of nucleic acid surrounded by protein coat known as an envelope.
- They cannot be grown on artifcial cell free media (However, grow in animals, eggs or tissue culture).
- Viruses do not have a cellular organization. They do not have cell wall or cell membrane or cellular organelles including ribosomes.
- They do not occur free in nature but act as obligate intracellular parasite.
- They lack the enzymes necessary for protein and nucleic acid synthesis and are dependent for replication on the synthetic machinery of host cells.

- They are unaffected by antibacterial antibiotics.
- Viruses are inert (nucleoprotein) filterable Agents
- Virus occupy a space in between living and non-living, because they are crystallizable and non-living outside the body of host.
- Obligate intracellular parasites of bacteria, protozoa, fungi, algae, plants, and animals.
- Ultramicroscopic size, ranging from 20 nm up to 450 nm (diameter)
- Do not independently fulfill the characteristics of life
- Inactive macromolecules outside the host cell and active only inside host cells
- Basic structure consists of protein shell (capsid) surrounding nucleic acid core.
- Nucleic acid of the viral genome is either DNA or RNA but not both.
- Nucleic acid can be double-stranded DNA, single-stranded DNA, single-stranded RNA, or double-stranded RNA.
- Molecules on virus surface impart high specif city for attachment to host cell.
- Multiply by taking control of host cell's genetic material and regulating the synthesis and assembly of new viruses
- Lack machinery for synthesizing proteins

Self-test

- How does a virus differ from a cell?
- Why does a virus need a host cell?
- Compared with cells, what is unusual about viral genomes?.

Structure of viruses

What is the structure of virus?

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

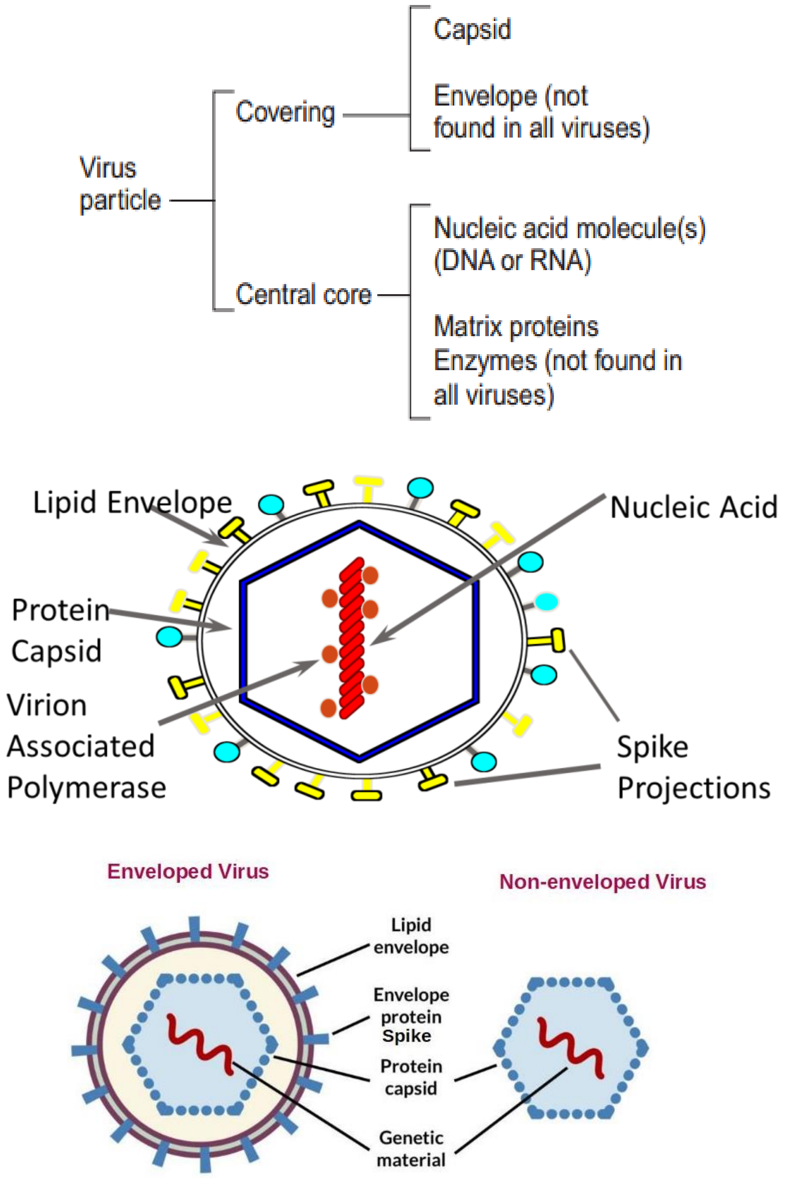


Figure 2.24. Viral Structure:

The basic structural components of a virus are;

Can you list the structural components of the virus?

Viruses have a very simple structure consists of the following

- **Core**-the genomic material, either DNA or RNA. DNA or RNA may be single-stranded or double stranded
- **Capsid**-a protective coat of protein surrounding the core
- **Nucleocapsid**- the combined structure formed by the core and capsid
- **Envelope**- a few viruses, such as the HIV and influenza viruses, have an additional lipoprotein layer around the capsid derived from the cell surface membrane of the host cell.
- **Capsomeres**- capsids are often built up of identical repeating subunits called capsomeres.
- Some virus contains enzymes which play central role during infection process. E.g., Some bacteriophage contains an enzyme **lysozyme**, which makes small hole in bacterial cell that allows viral nucleic acid to get in. Some virus contains their own nucleic acid **polymerase** which transcribe the viral genome into mRNA during replication process. E.g., Retrovirus are RNA virus that replicates inside host cell as DNA intermediate. These viruses possess an **RNA dependent DNA polymerase** called **reverse transcriptase**.

⚒ Self-test

Write down this exercise in your exercise book and **Fill the blank space with the appropriate** terms**)**

1. What is the name of the protein shell that surrounds the nucleic acid of a virus? -------------------------
2. What types of nucleic acid can a virus have DNA or RNA? --------------.
3. What is the term for the lipid and protein layer that some viruses have outside their capsid? ---------------------------.
4. What is the name of the process by which a virus takes over a host cell's machinery to make more viruses? --------------------------.
5. What is the name of the protein molecules on the surface of a virus that help it attach to a specific host cell? -----------------------------.

II. Viral symmetry

? What is viral symmetry? Can you list the type of viral symmetry? Dear learner, the listed below are the three type of viral symmetry's.

1. Helical symmetry

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

Icosahedral Symmetry

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

2. Complex Symmetry

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

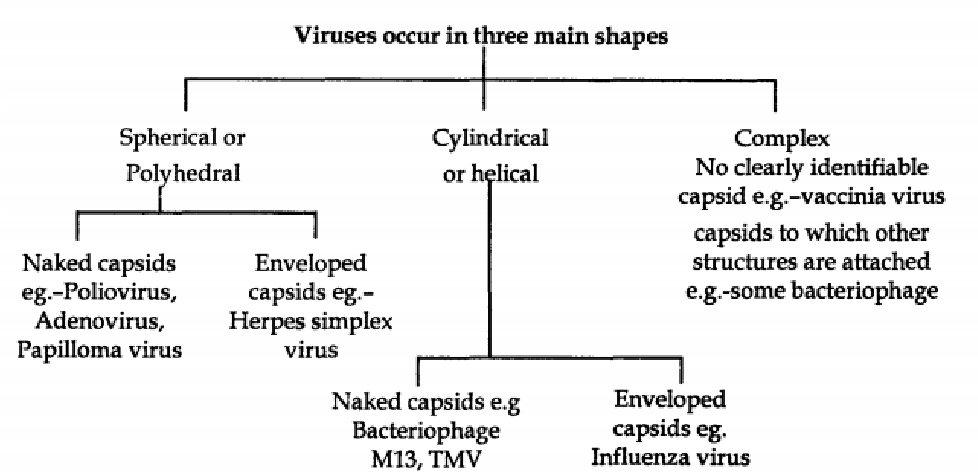
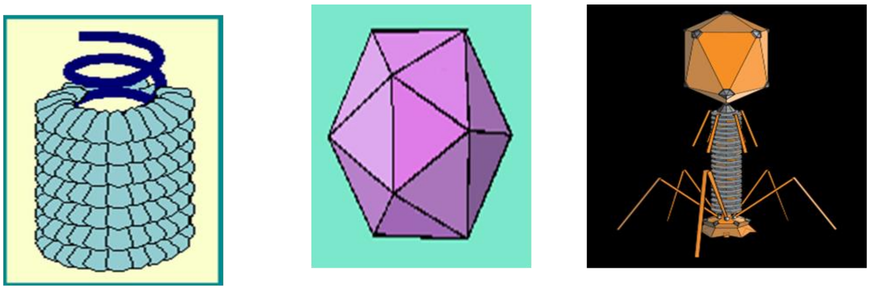


Figure 2.25. Viral classification based on their structures



Helical symmetry	Cubical symmetry	Complex symmetry
▪Corona virus ▪Influenza virus ▪Measles ▪Mumps	Adenovirus Epsten Bar Hepatitis A Hepatitis B Hepatitis C	T4 Bacteriophge

Figure:2.26A. Viral symmetry

Difference between DNA & RNA Viruses

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

Activity 2.4

- Briefly describe the two approaches a bacteriophage can take to trigger an infection once inside its host.

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

Self-test

Dear learner,

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

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

- **DNA virus** contains genetic information stored in the formof DNA
- **RNA virus** contains genetic information stored in the formof RNA
- **Retrovirus** an RNA virus that converts its genetic information from RNA intoDNA after it has infected ahost
- **Bacteriophage** a virus that uses a bacterium to replicate its genetic information

Classification of Viruses

Dear learner, Virus classification involves many complex processes. But at this stage it is described as follows. At this level the primary criteria for delineating the main viral taxa are:

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

(2) The strategy of viral replication, and

(3) The types of organisms they infect.

Self-test

- Contrast the ways in which animal and bacterial viruses enter their hosts.
- What is the difference between a persistent and a latent viral infection?
- How does viral infection of plants differ from viral infection of animals?

Viral Replication

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

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

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

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

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

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

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

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

- **Bacteriophage**

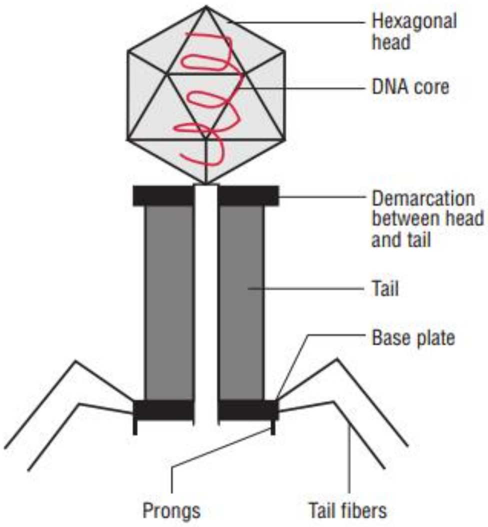


Figure 2.26B. bacteriophage

Self- test

? What do you know about bacteriophages? What is it use in biotechnology?

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

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

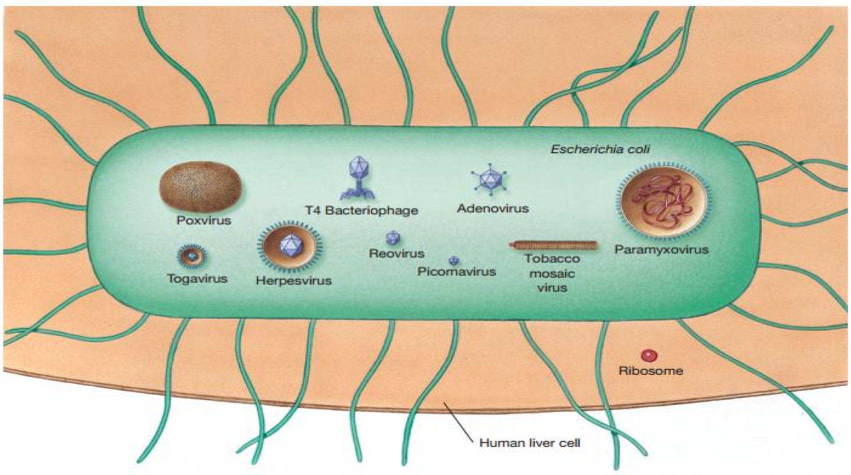


Figure 2.27. Variations in shapes and sizes of viruses compared with a bacterial cell, an animal cell, and a eukaryotic ribosome.

Phages exhibit two different types of life cycle:

What is the difference between lytic & Lysogenic cycle in viral replication?

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

The enzyme lysozyme, which is coded for by a phage gene, breaks down the cell wall, allowing viruses to escape. In the process the bacterial host cell is lysed.

Thus, phages such as T4 are called virulent (lytic) phages because they lyse and destroy the bacteria they infect. The released phages can now infect more susceptible bacteria, starting the infection process all over again. Such infections by virulent phages represent a lytic cycle of infection.

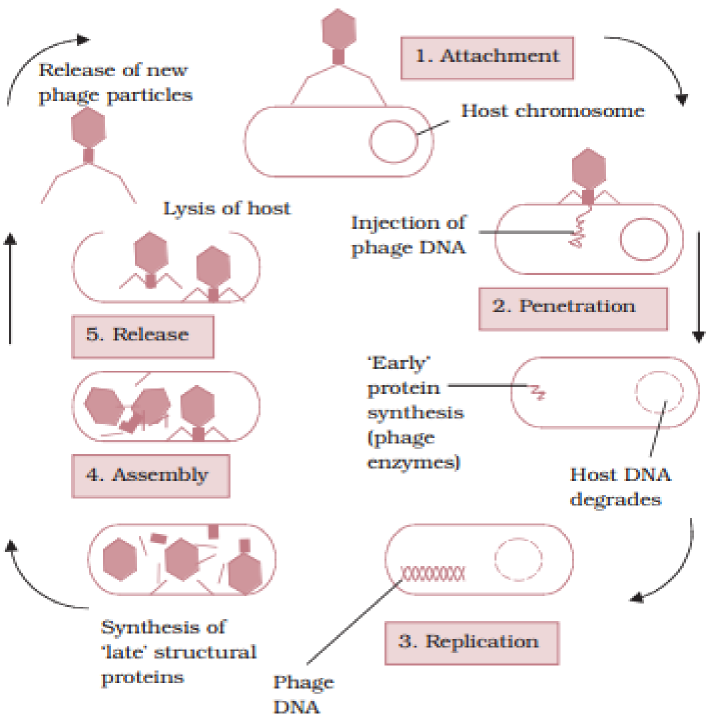


Figure 2.28. The lytic cycle of phage T4

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

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

The integrated phage nucleic acid is known as the prophage. The prophage behaves like a segment of the host chromosome and multiplies synchronously with it. This phenomenon is known as lysogeny. The bacterium that carries a prophage within its genome is called lysogenic bacterium and such phages are called lysogenic or temperate phages.

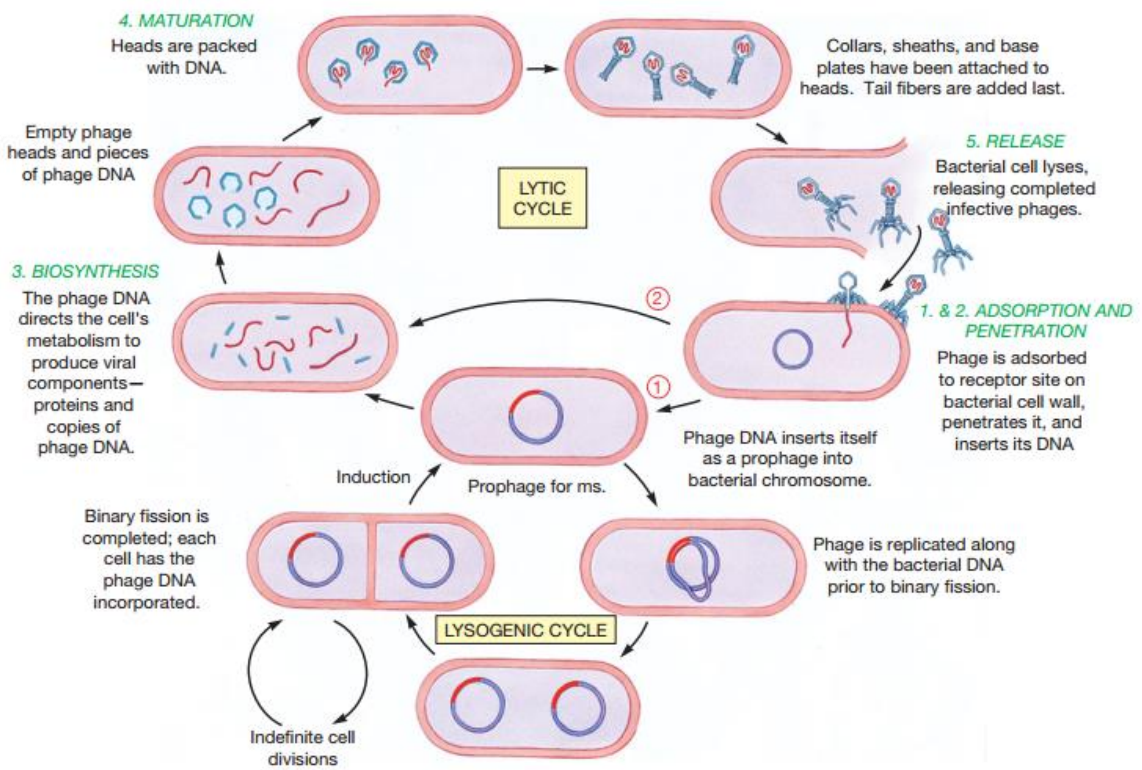


Figure 2.29. Lysogenic bacteriophage cycle (Replication of a temperate bacteriophage).

Lytic vs Lysogenic Cycle

Lytic Cycle	Lysogenic Cycle
The DNA of the virus doesn't integrate into the host DNA	The DNA of the virus integrates into the host DNA
Host DNA hydrolyzed	Host DNA not hydrolyzed
Absence of prophage stage	Presence of prophage stage
DNA replication of virus takes place independently from the host DNA replication	DNA replication of the virus takes place along with the host DNA replication
Occurs within a short period of time	Takes time
Symptoms of viral replication are evident	Symptoms of viral replication not evident
Genetic recombination in the host bacterium not allowed	Genetic recombination in the host bacterium allowed
The cellular mechanism of the host cell is totally undertaken by the viral genome	The cellular mechanism of the host cell is somewhat disturbed by the viral genome

Common viral diseases in Ethiopia

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

Table 2.7. Viral diseases

Disease	Causative agent	Sign and symptoms	Transmission	Prevention and control
Mumps	Mumps virus	Swollen and paifull protid glands .pain on chewing and swallowing	Person to person in infected saliva	vaccine

Measles (rubeola)	Measles virus	Caugh, nasal discharge, eye redness, and high fever,	Droplet contact	vaccine
Rabies	Rabies virus	Tingling, burning, coldness at bite site , Fever, headache, increased muscle, tension, Paralysis and hydrophobia	Bite from rabid animals	Avoiding rabid animals, thoroughly washing bitten area, pre-exposure vaccination when needed
Polio	Polio virus	Often no sign and symptoms	Fecal-oral-route	Polio vaccine, good personal hygien
Common cold ((rhinitis)	Rhinoviruses Adenoviruses & other viruses	Sneezing, sore throat, runny and stuffy nose, hacking cough	Respiratory droplets	Practicing good hygien
Chickenpox ((varicella)	Varicella-zoster virus	Fever, headache, malaise with red, itchy rash on face, scalp, chest, and back	Droplet contact	Hickenpox vaccine

Self-test

- How does attachment contribute to virus–host specificity?
- What is a lysogen and what is a prophage?
- How do temperate viruses differ from virulent (lytic) viruses?

🛠 Self-test

Write true if the statement is correct & false if the statement is incorrect

1. Viruses can be classified into four groups based on shape: filamentous, isometric, enveloped, and head and tail.
2. Viruses have organelles, ribosomes, and a plasma membrane.
3. Viruses can have either DNA or RNA as their genetic material, but not both.
4. Viruses can only infect eukaryotic cells, not prokaryotic cells.
5. Viruses can be detected by light microscopy, but not by electron microscopy.

✓ **Self-evaluation check list**

Put a tick (√) against each of the following tasks, which you can perform. If you cannot perform any of these tasks, go back and read the lesson for that particular task.

I Can:

S.no	Questions	✓ Check
1	• Give a brief definition of viruses.	
2	• describe the structures of a virus	
3	• Explain the characteristics of viruses.	
4	• Label the structures of viruses.	
5	• Justify why viruses must find an appropriate host cell to replicate themselves.	
6	• Classify viruses as RNA viruses and DNA viruses.	
7	• Explain the mechanism of replication viruses.	
8	• Distinguish between lytic and lysogenic cycle of a virus.	
9	• Describe the ways of transmission and prevention of HIV/AIDS, Hepatitis B.	
10	• Mention the common viral diseases in Ethiopia.	

SECTION 2.8. NORMAL MICROBIOTA

INTRODUCTION

☸ Dear learner, I am pleased to see that you have grasped the concepts of bacteria, fungi, protozoa, and viruses in the previous lesson. In this topic, you will delve deeper into the world of microflora and explore the difference between resident and transient bacteria, as well as learn about the protective role of normal microflora. You will also review the germ theory of disease and Koch's postulates, which are fundamental principles in microbiology. You will also find how Koch's justifications have contributed to the development of microbiological techniques.

I hope that you will find this topic engaging and informative. Remember to ask questions and seek clarification if you encounter any difficulties. Keep up the good work!

MINIMUM LEARNING COMPETENCIES

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

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

Dear learner, do you know what a normal microbiota is? The **normal microbiota** is the population of microorganisms routinely found growing on the body of healthy individuals. Microbes that typically inhabit body sites for extended periods are resident microbiota, whereas temporary occupants are called **transient microbiota** (See Figure 2.30).

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

1. An understanding of the different microorganisms at particular locations provides greater insight into the possible infections that might result from injury to these body sites.
2. Knowledge of the normal microbiota helps the physician investigator understand the causes and consequences of colonization and growth by microorganisms normally absent at a specific body site.
3. An increased awareness of the role that these normal microbiota play in stimulating the host immune response can be gained. This awareness is important because the immune system provides protection against potential pathogens.

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

(1) Covering binding sites that might otherwise be used for attachment,
(2) Consuming available nutrients,
(3) Producing compounds toxic to other bacteria,
(4) To stimulate the adaptive immune system.

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

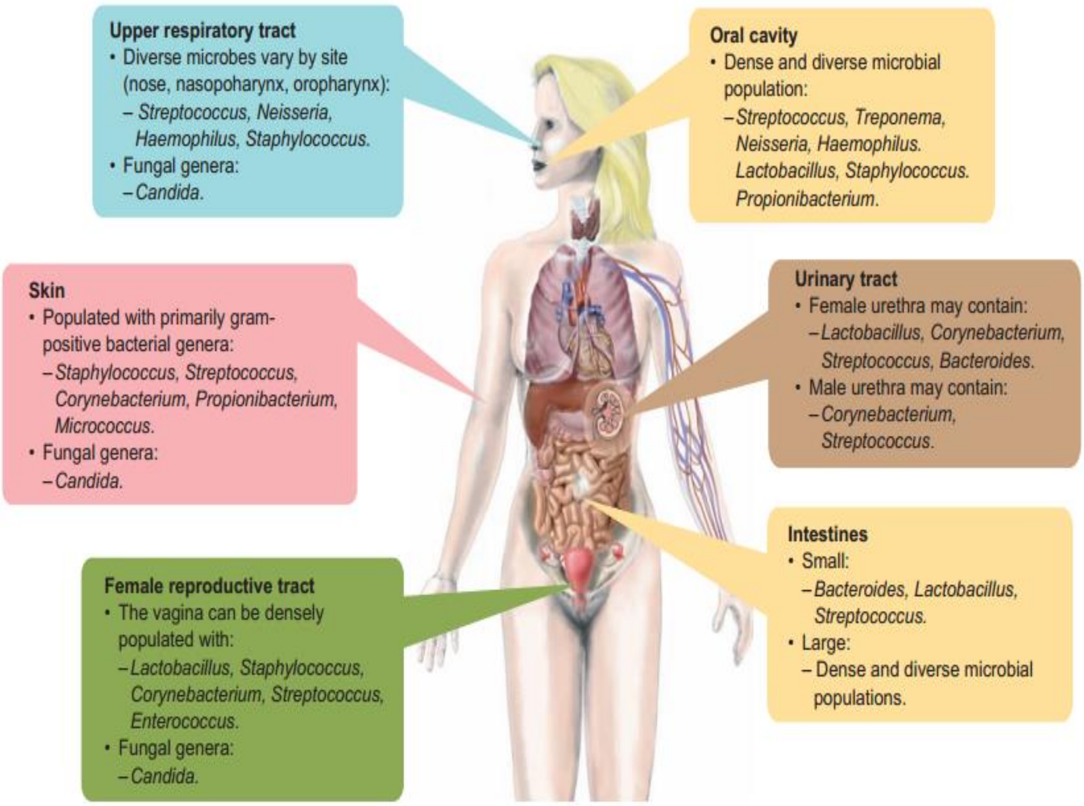


Fig 2. 30. Normal microbionta of the human body

🛠 Self-test

Fill the blank space by the appropriate answer

1. The human ______________is the sum total of all microorganisms that live on or in the human body.
2. The normal microbiota refers to the microorganisms that reside on the surface and deep layers of ________, in the saliva and oral ________, in the conjunctiva, and in the gastrointestinal _______ of every human being.
3. The normal microfloras have developed a __________ relationship with the mammalian host, meaning they co-exist without harming humans.
4. The normal microflora can help maintain our health by promoting immune system development, regulating metabolism, and protecting against __________ microorganisms.
5. The normal microflora can vary in composition and location depending on factors such as age, diet, hygiene, _________, and medication.

The Germ Theory of Disease and Koch's Postulates

Dear learner, have you ever heard of Germ Theory of Disease and Koch's Postulates? What does this theory teach us about? So under this topic you will learn the message of this theory.

In order to prove whether or not diseases are caused by microorganisms, Koch used mice in his experiment. Using appropriate controls, Koch demonstrated that when a small amount of blood from a diseased mouse was injected into a healthy mouse, the latter quickly developed anthrax. He took blood from this second animal, injected it into another, and again observed the characteristic disease symptoms (Figure 2.31). However, Koch carried this experiment a critically important step further. He discovered that the anthrax bacteria could be grown in nutrient fluids outside the host and that even after many transfers in laboratory culture, the bacteria still caused the disease when inoculated into a healthy animal. On the basis of these experiments and others on the causative agent of tuberculosis, Koch formulated a set of rigorous criteria, now known as **Koch's postulates**, for definitively linking a specific microorganism to a specific disease. Koch's postulates state the following:

1. The disease-causing organism must always be present in animals suffering from the disease but not in healthy animals.
2. The organism must be cultivated in a pure culture away from the animal body.
3. The isolated organism must cause the disease when inoculated into healthy susceptible animals.
4. The organism must be isolated from the newly infected animals and cultured again in the laboratory, after which it should be seen to be the same as the original organism

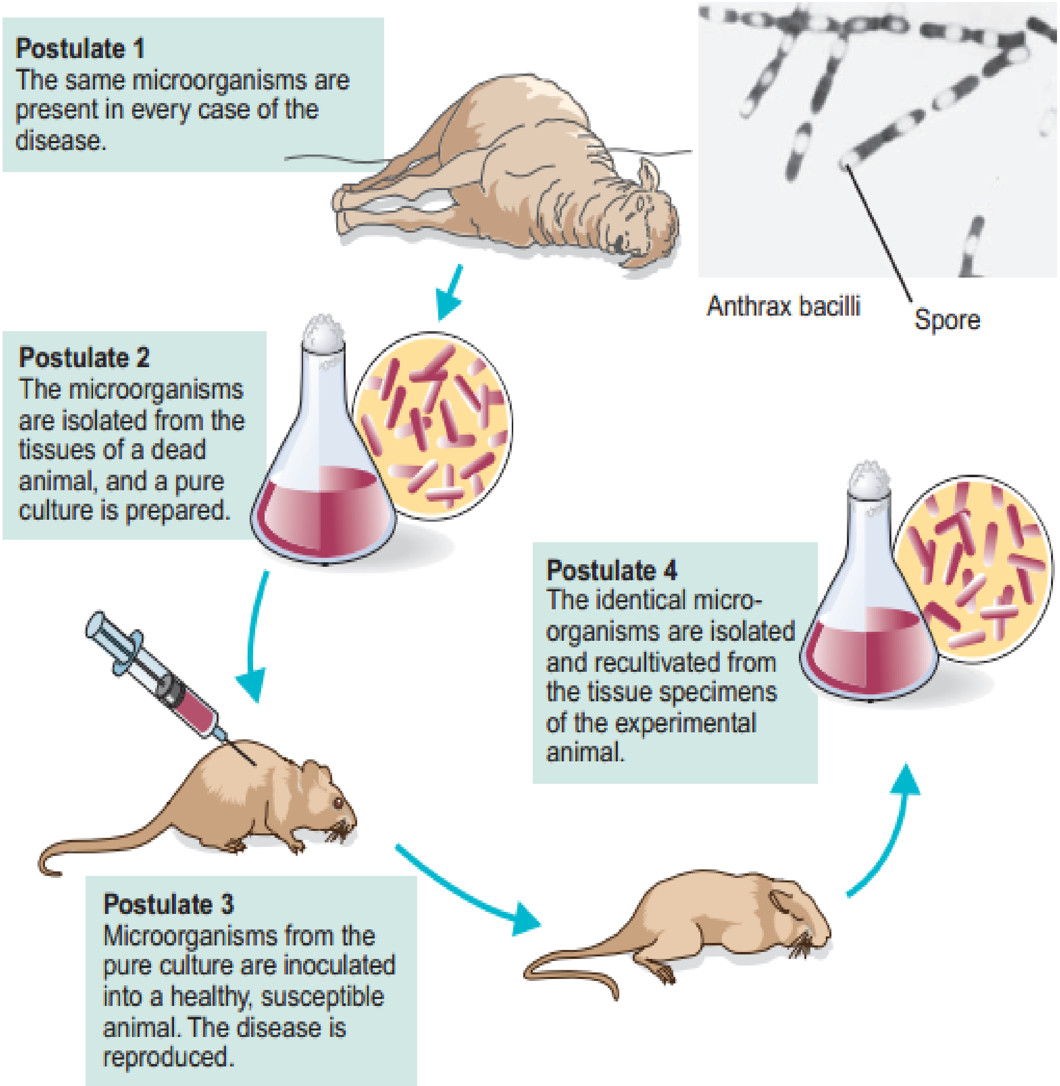


Figure 2.31. Koch's postulate

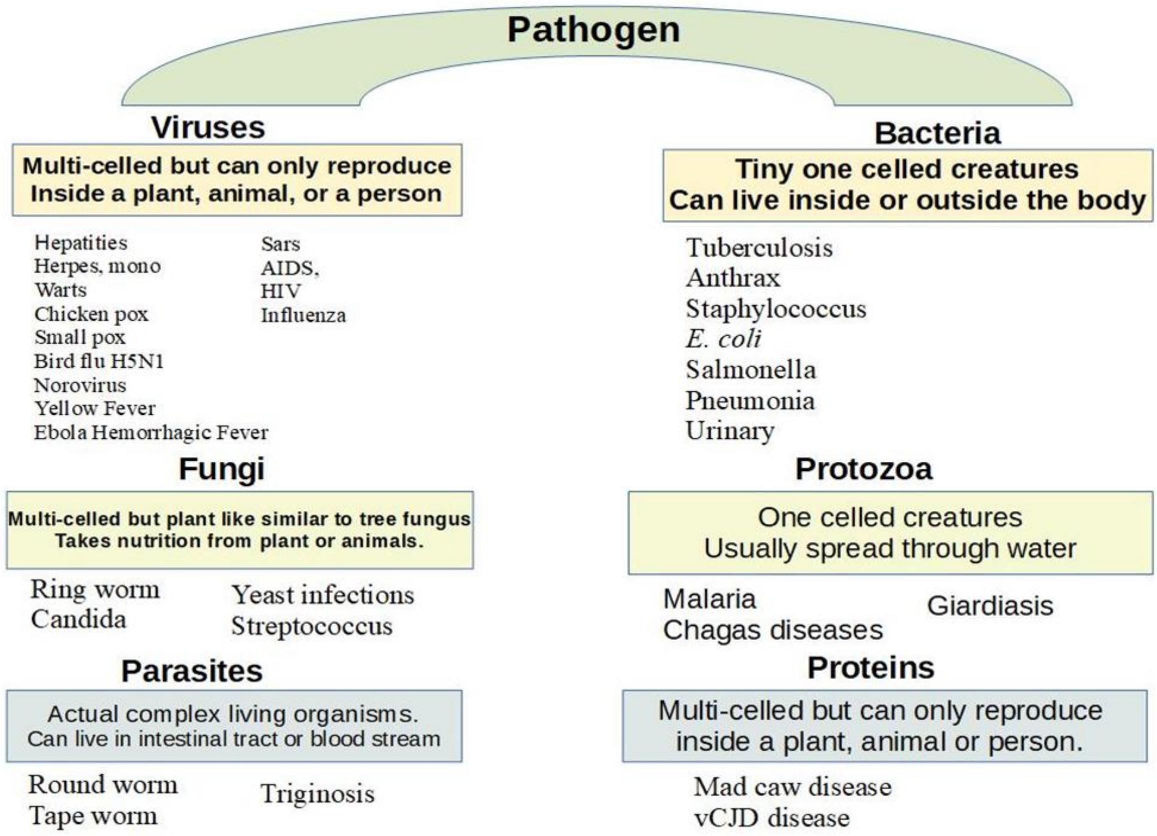
What you understand for the above image (Figure 2.31)?

Self-test

- Define normal microbiota and transient microbiota.
- Contrast normal microbiota and transient microbiota with opportunistic microorganisms
- Differentiate normal microbiota and infectious disease.
- How can opportunistic pathogens cause infections?
- What factors contribute to the emergence of an infectious disease?

Keywords

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



Activity 2.5

Prepare a report summarizing the germ theory of disease in your own words and explaining the importance of Koch's postulates. Submit your report to the tutor.

✓ **Self-evaluation check list**

Put a tick (√) against each of the following tasks, which you can perform. If you cannot perform any of these tasks, go back and read the lesson for that particular task.

I Can:

S.no	**Questions**	✓ **Check**
1	• Define the normal microbiota.	
2	• Distinguish between resident and transient microbiota	
3	• Mention three protective roles of the normal microbiota.	
4	• Explain how the composition of the normal microbiota can change over time.	
5	• Describe germ theory of diseases.	
6	• State at least three postulates formulated by Koch.	
7	• Justify how the Koch's experimental procedure contributed to the advancement microbiological techniques.	

SECTION 2.9. MODES OF DISEASE TRANSMISSION AND WAYS OF PREVENTION

INTRODUCTION

☸ **Dear learner**, I hope you may aware of covid -19. This disease is highly contagious and can be transmitted from human to human, as well as from humans to animals. This highlights the importance of understanding the modes of transmission for various diseases. In this topic, you will explore the different ways that diseases can be spread, including through direct contact, airborne transmission, and vector-borne transmission.

By understanding how diseases are transmitted, we can take steps to prevent their spread and protect ourselves and those around us. I encourage you to stay informed about COVID-19 and other infectious diseases, and to follow recommended guidelines for staying safe.

MINIMUM LEARNING COMPETENCIES

In this lesson, learner will be able to:

- Describe the modes of disease transmission.
- Give examples of airborne diseases.
- Give examples of food and waterborne diseases.
- Describe how vector borne diseases are transmitted.

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

- Contact,
- Droplet
- Airborne
- Common vehicle

Self-Test Write true for correct statement or False if not

1. Direct contact transmission occurs when a person with an infectious disease touches or exchanges body fluids with someone else.
2. Airborne transmission requires close proximity between the source and the susceptible person.
3. Contaminated food and water are examples of vehicle transmission.
4. Animal-to-person transmission can only occur through bites or scratches.
5. Handwashing is an effective way to prevent many types of disease transmission.

Table 2.8. Modes of disease transmission

Method of transmission	How the transmission route works	Examples of diseases
Droplet infection	Many of these diseases are 'respiratory diseases' – diseases affecting the airways of the lungs. The organisms are carried in tiny droplets through the air when an infected person coughs orsneezes. They are inhaled by other people.	Common cold, 'flu, pneumonia
Drinking contaminate dwater	The micro-organisms transmitted in this way often infect regions of the gut. When unclean water containing the organisms is drunk,they colonise a suitable area of the gut and reproduce. They are passed out with faeces and find their way back into the water.	Cholera, typhoid fever
Eating contaminate d food	Most food poisoning is bacterial, but some viruses are transmittedthis way. The organisms initially infect a region of the gut.	Salmonellosis, typhoid fever, listeriosis, botulism
Direct Contact	Many skin infections, such as athlete's foot, are spread by direct contact with an infected person or contact with a surface carryingthe organism.	Athlete's foot, ringworm
Sexual intercourse	organisms infecting the sex organs can be passed from one sexualpartner to another during intercourse. Some are transmitted by direct body contact, such as the fungus that causes candidiasis (thrush). others are transmitted in semen or vaginal secretions, such as the AIDS virus. Some can be transmitted in saliva, such assyphilis.	Candidiasis, syphilis, AIDS, gonorrhoea
Blood-to-blood contact	Many of the sexually transmitted diseases can also be transmittedby blood-to-blood contact. Drug users sharing an infected needle can transmit AIDS.	AIDS, hepatitis B
Animal vectors	Many diseases are spread through the bites of insects. Mosquitoes spread malaria and tsetse flies spread sleeping sickness. in both cases, the disease-causing organism is transmitted when the insect bites humans in order to suck blood. Flies can carry micro- organisms from faeces onto food.	Malaria, sleeping sickness

Activity 2.6

Prepare a summary and report it to your tutor on the following questions. What is the role of reservoir hosts in the transmission of parasitic diseases? How do reservoir hosts contribute to the epidemiology of diseases like leishmaniosis? Discuss the challenges in controlling parasitic diseases due to the presence of reservoir hosts. Examine the importance of understanding host-parasite relationships in developing treatments for parasitic diseases. Evaluate the impact of environmental changes on the dynamics of reservoir hosts and parasitic diseases. These questions and answers provide a starting point for an in-depth exploration of the topic. For a more detailed discussion, it is important to delve into specific case studies and current research findings.

✓ **Self-evaluation check list**

Put a tick (√) against each of the following tasks, which you can perform. If you cannot perform any of these tasks, go back and read the lesson for that particular task.

I Can:

S.no	Questions	✓ Check
1	• Describe the modes of disease transmission.	
2	• Give examples of airborne diseases.	
3	• Give examples of food and waterborne diseases.	
4	• Describe how vector borne diseases are transmitted.	

SECTION 2.10. USES OF MICROORGANISMS

INTRODUCTION

☸ Dear learner, you have learned well how diseases are transmitted from the previous lessons. In this topic, you will explore the importance of microorganisms in various fields and processes, such as agriculture, sewage treatment, bioremediation, food production and processing, medicine, biotechnology, and recycling minerals through ecosystem. You will learn more details about these topics in this lesson.

MINIMUM LEARNING COMPETENCIES

In this lesson, you will be able to:

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

Dear learner, how can we understand the benefits of microorganisms?

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

What are the roles of microorganisms in **agriculture?**

Self-test

Dear learner,

- Discuss the importance of microorganisms in the environment as well as their practical importance.
- Assess the role of microorganism decomposition on global carbon flux?

- **Agriculture**

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

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

The chemical elements carbon, nitrogen, oxygen, sulfur, and phosphorus are essential for life and abundant, but **not necessarily in forms that organisms can use.** Therefore, microorganisms are primarily responsible for converting these elements into forms that plants and animals can use. Microorganisms, especially bacteria and fungi, return carbon dioxide to the atmosphere when they decompose organic wastes and dead plants and animals. Algae, cyanobacteria, and higher plants use the carbon dioxide during photosynthesis to produce carbohydrates for animals, fungi, and bacteria. Nitrogen is abundant in the atmosphere but in a form not usable by plants and animals. Only bacteria can naturally convert atmospheric nitrogen to a form available to plants and animals (nitrate) (Figure 2.19).

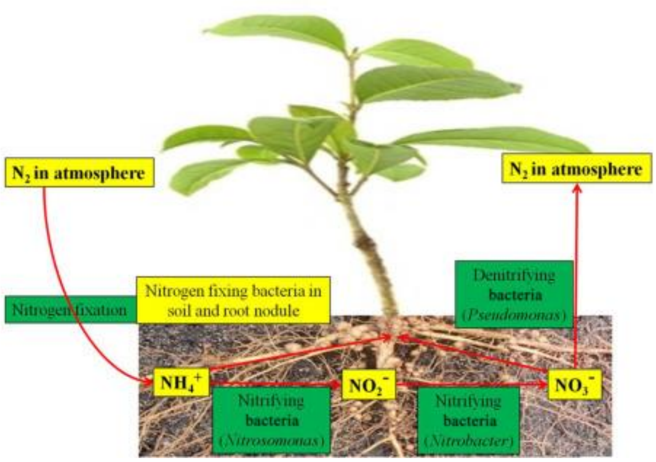


Figure 2.32. The role of microorganisms in agriculture

Self-Test

Write <u>true</u> if the statement is correct and <u>false</u> if the statement is incorrect.

1. Microorganisms can help in supplying nutrients, controlling diseases, and degrading wastes in agriculture.
2. Microorganisms can only harm plants by causing diseases, pests, and weeds.

3. Microorganisms can produce antibiotics that can be used to treat plant infections.

Sewage treatment

What process cleans wastewater and prevents pollution?

Dear learner, Sewage treatment is the process that removes impurities from wastewater, or sewage, before it reaches aquifers or natural bodies of water such as rivers, lakes, estuaries, and oceans, and aims to produce an effluent that is suitable to discharge to the surrounding environment or an intended reuse application, thereby preventing water pollution from raw sewage discharges. Anaerobic bacteria are used in wastewater treatment on a normal basis. The main role of these bacteria in sewage treatment is to reduce the volume of sludge and produce **methane gas** from it. **Methane gas** can be used as an **alternative energy source**. This is a huge benefit considering the already high wastewater treatment energy consumption levels. **Phosphorus removal** from wastewater is another benefit of anaerobic microbes used in sewage treatment (Figure 2.33).

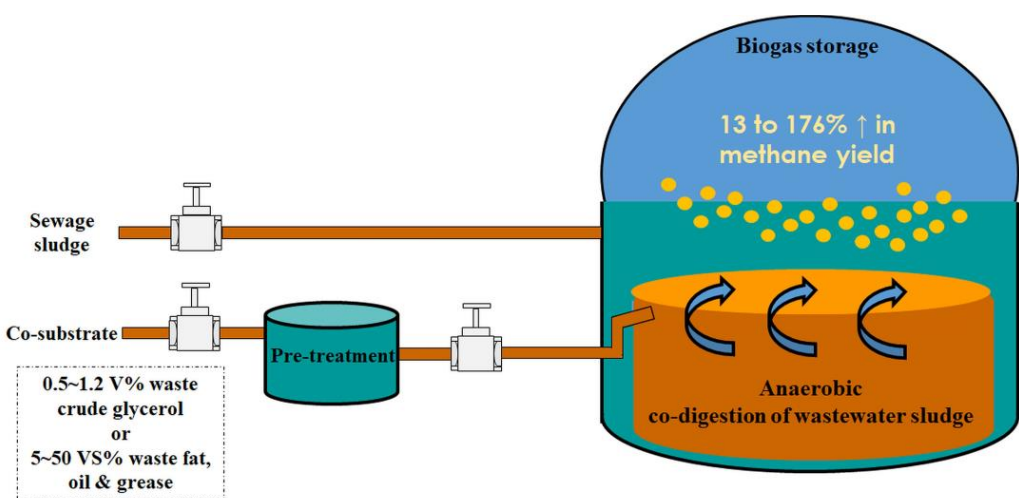


Figure 2.33. Anaerobic co digestion of waste water.

- **Bioremediation**

?	What is bioremediation?

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

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

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

Self-Test

Choose the appropriate answer from the given alternatives.

1. Which of the following is NOT a bioremediation technique?

a) Phytoremediation b) Bioaugmentation c) Incineration d) Biostimulation

2. Bioremediation is a process that uses __________ to degrade or remove pollutants from contaminated sites.

   a) Chemicals b) Microorganisms c) Mechanical devices d) Heat treatment

3. What is the main advantage of using bioremediation over traditional remediation methods?

   a) It is faster and more efficient. b) It requires less equipment and manpower.

   c) It is less expensive. d) It does not produce any harmful byproducts.

- **Food production and processing**

Dear learner, what is the role of Microorganisms in food production and processing? Microorganisms not only spoiling the food, but they also have a significant role in food preparation. For example, the tart taste of yogurt, pickles, sharp cheeses, and some sausages is due to the production of lactic acid by one or more members of a group of bacteria known as the lactic acid bacteria. These bacteria - including species (Figure 2.34) of *Lactobacillus, Lactococcus, Streptococcus, Leuconostoc,* and *Pediococcus* are obligate fermenters that characteristically produce lactic acid as an end product of their metabolism. Some also produce flavorful and aromatic compounds that contribute to the overall quality of fermented foods.

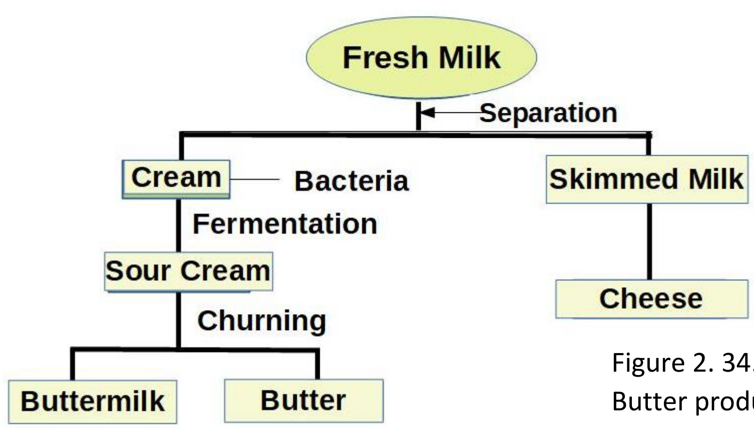


Figure 2. 34. The role of Bacteria in Butter production

Self-Test

Match the following sentence with appropriate terms.

S.no	A) Fermentation B) Probiotics C) Cheese D) Bread E) Yogurt	
1	A process that converts sugars into acids, gases or alcohol by microorganisms, such as yeast or bacteria.	
2	Live microorganisms that confer health benefits to the host when consumed in adequate amounts, such as lactobacilli or bifidobacteria	
3	A dairy product that is made by coagulating milk proteins with enzymes or acids and then separating the solid curds from the liquid whey.	
4	A baked product that is made by mixing flour, water, salt and yeast and then allowing the dough to rise and form air bubbles.	
5	A fermented milk product that is made by adding specific cultures of bacteria, such as Streptococcus thermophilus and Lactobacillus bulgaricus, to pasteurized milk.	

- **Medicine**

What is the role of microbial metabolites in treating diseases?

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

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

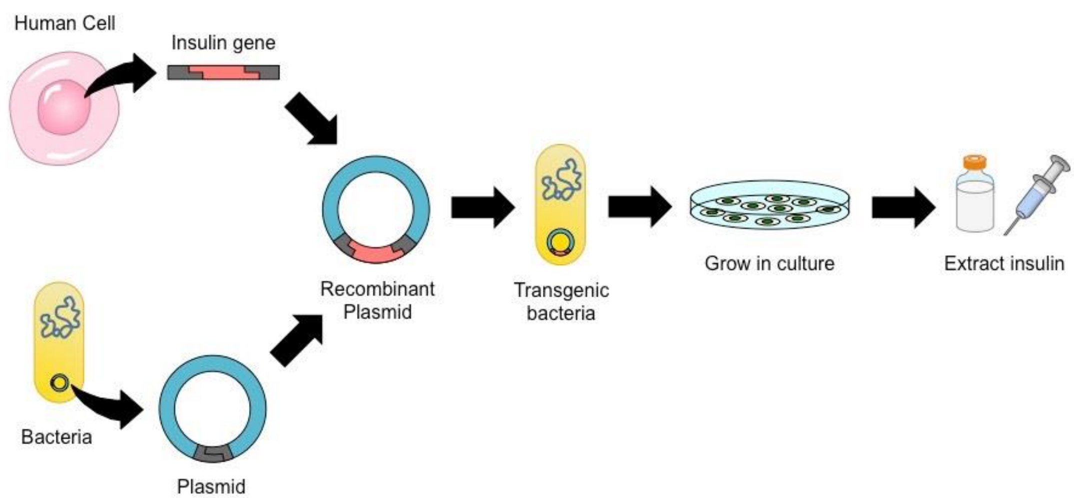


Figure 2.35. Gene transfer to produce human insulin in bacteria. Source. BioNInja

- **Health**

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

What is the role of microorganism in Medicine?

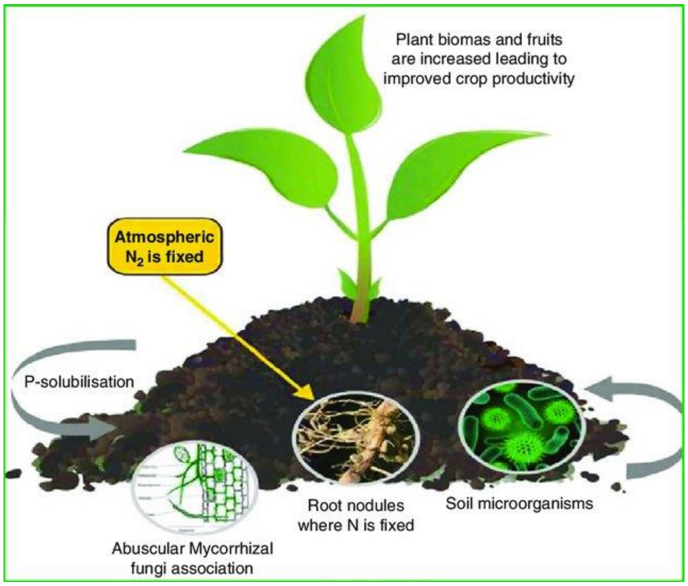
- **Biotechnology**

What is biotechnology?

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

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

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



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

The role of bacteria in recycling minerals through ecosystems

What is the roles of microorganisms in maintaining the ecosystem?

Many bacteria are decomposers. When organisms die, these bacteria break down the complex molecules that are found in the bodies of the dead organisms into much simpler molecules. The bacteria use some of these for their own metabolism, but in the process, they release some minerals (Figure2. 24), in various forms, into the environment.

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

The carbon cycle

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

Carbon Fixation

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

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

Methanogenesis and Methane Oxidation

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

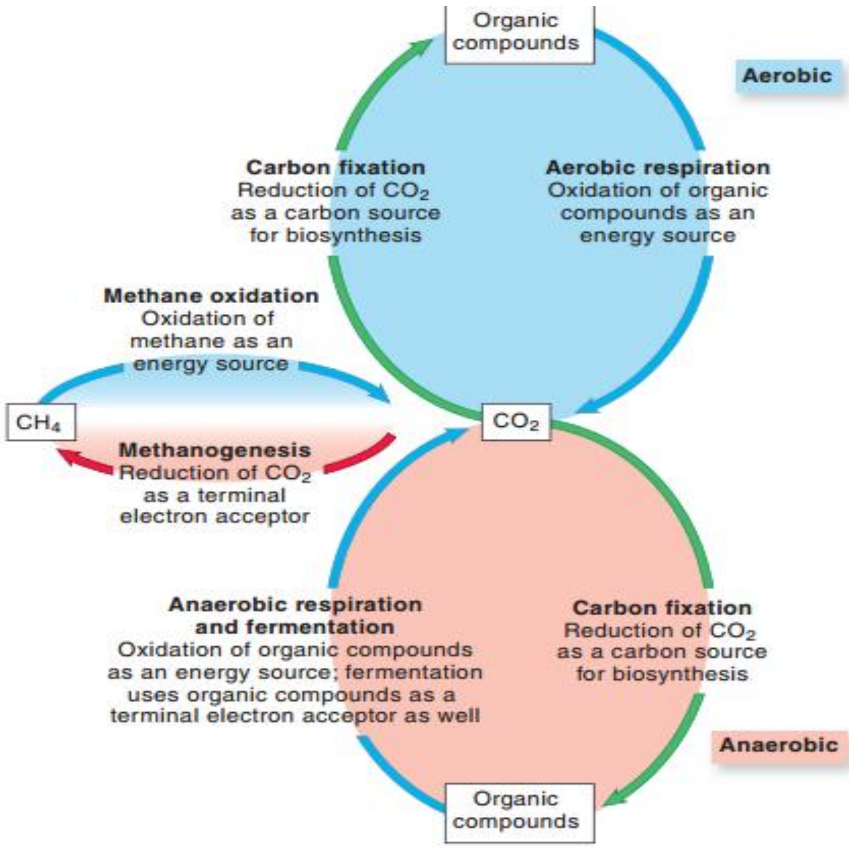


Figure 2.37. The carbon cycle

The Nitrogen cycle

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

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

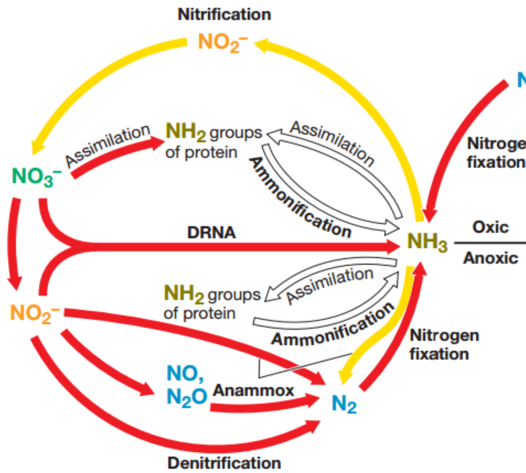


Figure 2.38. The nitrogen cycle

The sulfur cycle

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

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

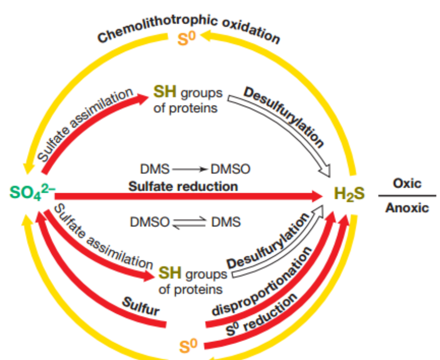


Figure 2.39. The sulfur cycle

The phosphorus cycle

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

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

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

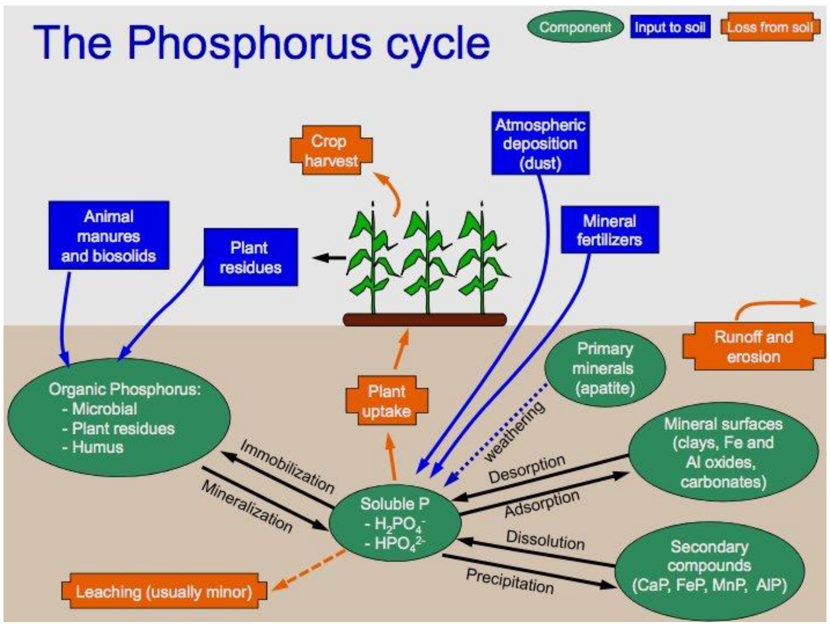


Figure 2.40. The phosphorus cycle

Self-Test

Choose the appropriate answer from the given alternatives.

1) Which of the following is NOT a role of bacteria in recycling minerals through ecosystems?

a) Nitrogen fixation b) Decomposition of organic matter

c) Phosphorus absorption from the soil d) Carbon cycling

2) Bacteria are important in the phosphorus cycle because they:

a) Convert phosphorus into a usable form for plants

b) Absorb excess phosphorus from the soil

c) Release phosphorus into the atmosphere through respiration

d) Break down (solubilize) phosphorus-rich minerals in the soil

3. Bacteria contribute to the sulfur cycle by:

a) Absorbing sulfur dioxide from the atmosphere

b) Producing sulfur dioxide through respiration

c) Decomposing organic matter and releasing sulfur compounds

d) Fixing sulfur into organic compounds through photosynthesis

✓ **Self-evaluation check list**

Put a tick (√) against each of the following tasks, which you can perform. If you cannot perform any of these tasks, go back and read the lesson for that particular task.

I Can:

S.no	**Questions**	✓ **Check**
1	• Explain the various uses or application of microorganisms.	
2	• Explain the medical application.	
3	• Describe how vector borne diseases are transmitted.	

SECTION 2.11. CONTROLLING MICROORGANISMS

INTRODUCTION

☸ **Dear learner**, as you know, microorganisms can be both beneficial and harmful to humans and the environment. Therefore, it is essential to control their growth and spread to prevent diseases and maintain a healthy ecosystem.

In this topic, we will explore the different methods used to control microorganisms, such as physical, chemical, and biological methods. We will also discuss the importance of proper sanitation practices and how they can prevent the spread of harmful microorganisms.

MINIMUM LEARNING COMPETENCIES

In this section, you will be able to,

- Define sterilization
- Explain the type of sterilization

? What is sterilization?

Dear learner, sterilization is the process of killing or removing all living microorganisms from an object or medium. Sterile means free of any microbes. Physical agents, such as heat, or by chemical agents, called sterilants, can do sterilization. Germicides are chemicals that kill pathogenic microbes, but not necessarily spores. They can be used on living tissue or inanimate materials. Disinfection is the use of chemicals that destroy or remove most pathogens, but not spores, from inanimate objects. Disinfectants can also remove toxins produced by microbes. Different techniques are used to remove or reduce the number of microorganisms from a material/objects.

Antiseptics and Sanitization

Dear learner, antiseptics are chemicals that are applied to living tissue, such as skin or wounds, to kill or inhibit vegetative pathogens. Sanitization is the mechanical removal of microbes and debris from objects to reduce contamination. Sanitizers are compounds that are used for this purpose.

Decontamination

Dear learner, can define decontamination? **Decontamination** is the reduction of microbial contamination of an object. Aseptic measures and techniques are used to prevent microbial contamination of materials or wounds.

Heat Methods

Heat is a simple, cheap and effective way of killing microbes. Heat can be applied in different ways, depending on the product and the purpose.

Pasteurization is a method of heating liquids, such as milk, to kill most pathogens and extend shelf life. Pasteurization can be done at low or high temperatures, for different durations. Uperization is a method of heating liquids to very high temperatures for a short time, using steam and pressure, to kill all microbes and spores.

Disinfection by heat involves boiling medical instruments, needles, syringes, etc. for a certain time. However, this does not ensure sterilization, as some bacterial spores can survive boiling.

Dry heat sterilization involves exposing objects to high temperatures for a long time. This can be done by flaming, incineration, or hot air oven. Flaming is used for inoculating loops, forceps, spatulas, etc. Incineration is used for destroying infectious materials by burning them to ashes. Hot air oven is used for sterilizing glassware, metal instruments, powders, oils, etc.

Moist heat sterilization involves using autoclaves with saturated, pressurized steam. This is more effective than dry heat sterilization, as steam penetrates better and kills spores. Autoclaves can be operated at different temperatures and pressures for different times. The heating and cooling times must be considered to ensure complete sterilization.

Intermittent sterilization involves exposing objects to moist heat for a short time on three successive days. This allows the spores to germinate into vegetative cells that are more susceptible to heat. This method is used for sterilizing culture media and solutions that cannot withstand high temperatures or pressures.

Self-Test

Choose the correct answer for the following questions.

1. Which of the following is a physical agent that can be used to sterilize objects or media?
   A) Heat B) Disinfectant C) Antiseptic D) Antibiotic
2. Which of the following is a chemical agent that can be used to kill pathogenic microbes on living tissue?
   A) Germicide B) Sterilant C) Antiseptic D) Sanitizer
3. Which of the following is a method of heating liquids to kill most pathogens and extend shelf life?
   A) Disinfection B) Pasteurization C) Uperization D) Incineration
4. Which of the following is a method of mechanical removal of microbes and debris from objects to reduce contamination?

   A) Preservation B) Decontamination C) Sanitization D) Aseptic technique

✓ **Self-evaluation check list**

Put a tick (√) against each of the following tasks, which you can perform. If you cannot perform any of these tasks, go back and read the lesson for that particular task.

I Can:

S.no	Questions	✓ Check
1	• Define sterilization	
2	• Explain the type of sterilization	

SECTION 2.12. BACTERIAL ISOLATION TECHNIQUES

INTRODUCTION

Dear learner, I hope you have understood the benefits of microorganisms from the previous lessons. Microorganisms are ubiquitous organisms that can be isolated, identified, and applied for different purposes. So, in this topic you will learn in detail how to isolate microorganisms

MINIMUM LEARNING COMPETENCIES

In this section, you will be able to:

- Explain the technique of microorganism isolation from different sources

How microorganisms are isolated from different sources?

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

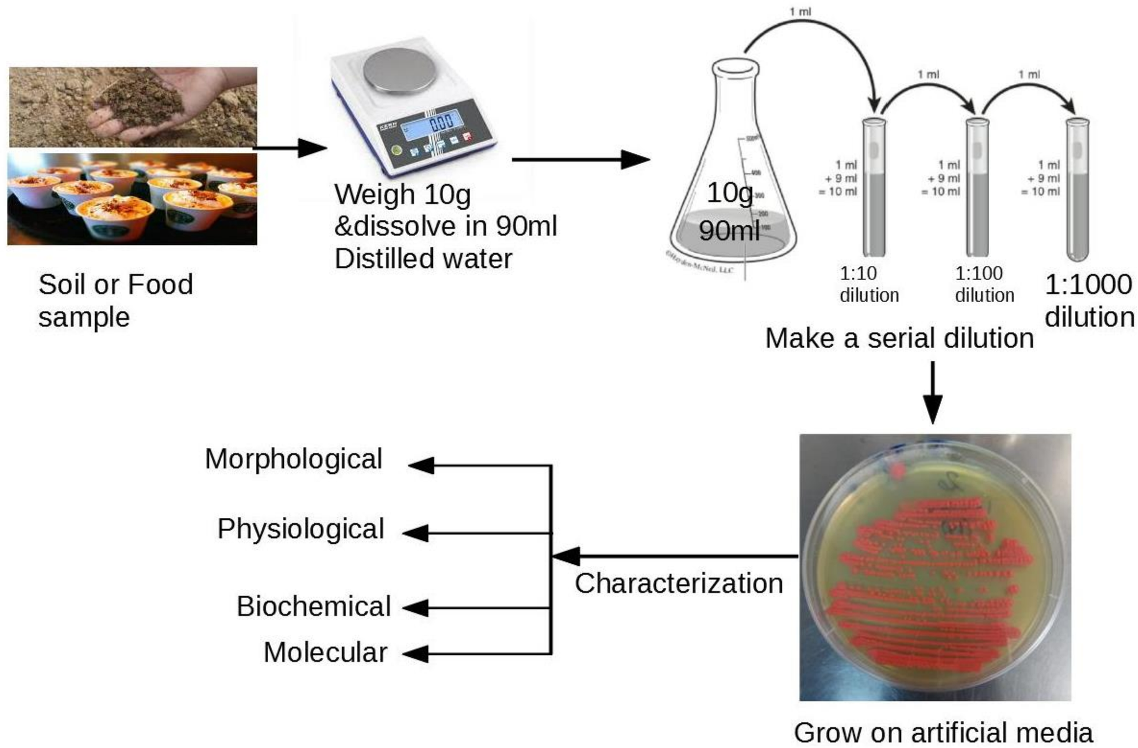


Figure 2.41. Technique for microbial isolation from environmental or food samples

What is serial dilution? Why we do a serial dilution?

Section 2.13. Renowned Microbiologists in Ethiopia

Activity 2. 7

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

Unit summary

- Microorganisms are very diverse and are found in all three domains of life: Archaea, Bacteria, and Eukarya.
- Archaea and bacteria are classified as prokaryotes because they lack a cellular nucleus.
- Archaea differ from bacteria in evolutionary history, genetics, metabolic pathways, and cell wall and membrane composition.
- Archaea inhabit nearly every environment on earth, but no archaea have been identified as human pathogens.
- Eukaryotes studied in microbiology include algae, protozoa, fungi, and helminths.
- Algae are plant-like organisms that can be either unicellular or multicellular, and derive energy via photosynthesis.
- Protozoa are unicellular organisms with complex cell structures; most are motile. Microscopic fungi include molds and yeasts.
- Helminths are multicellular parasitic worms.
- They are included in the field of microbiology because their eggs and larvae are often microscopic.
- Viruses are acellular microorganisms that require a host to reproduce.
- The field of microbiology is extremely broad. Microbiologists typically specialize in one of many subfields, but all health professionals need a solid foundation in clinical microbiology

Unit summary question

1. Which of the following is not a characteristic of bacteria?
   a. are prokaryotic
   b. have peptidoglycan cell walls
   c. have the same shape
   d. grow by binary fission

e. have the ability to move

2. Which of the following is the most important element of Koch's germ theory of disease? The animal shows disease symptoms when
   a. The animal has been in contact with a sick animal.
   b. The animal has a lowered resistance.
   c. A microorganism is observed in the animal.
   d. A microorganism is inoculated into the animal.
   e. Microorganisms can be cultured from the animal.
3. It has been said that bacteria are essential for the existence of life on Earth. Which of the following is the essential function performed by bacteria?
   a. control insect populations
   b. directly provide food for humans
   c. decompose organic material and recycle elements
   d. cause disease
4. What is the term for the process by which viruses invade cells and subvert them to produce new virions?
   a. Infection b). Replication c). Transduction d). Transformation
5. What is the name of the protozoan that causes malaria?
   a. Entamoeba b. Giardia c. Plasmodium d. Trypanosoma
6. What are some of the products that bacteria can synthesize for industrial purposes?
   a. Antibiotics, enzymes, vitamins and bioplastics
   b. Alcohols, acids, gases and biofuels
   c. Proteins, hormones, vaccines and antibodies
   d. All of the above
7. The rod-shaped bacteria are called__________________________.
   a) Coccus b) Bacillus c) Spiral d) Pleomorphic
8. ____________________is the use of microorganisms to produce substances such as antibiotics, enzymes, and hormones.
   a) Microbial fermentation b) Microbial biocontrol c). Microbial bioremediation d). Microbial biocatalysis

9. _______________is the use of microorganisms to degrade or transform pollutants and contaminants in the environment.

a) Microbial bioremediation b). Microbial biocontrol c). Microbial biosynthesis d). Microbial bioconversion

10. The use of microorganisms to control or suppress pests and diseases in plants and animal is known as ___________________________.

a) Microbial biocontrol
b) Microbial bioremediation
c) Microbial biopreservation
d) Microbial biofertilization

11. A hypha divided into compartments by cross walls is called________.

a. nonseptate b. imperfect c. septate d. perfect

12. The uses of microorganisms to produce or enhance the nutritional value of food and feed products are called_______________________.

a) Microbial biosynthesis
b) Microbial biopreservation
c) Microbial biofortification
d) Microbial bioconversion

- ✓ **Self-evaluation check list**

Put a tick (√) against each of the following tasks which you can perform. If you cannot perform any of these tasks, go back and read the lesson for that particular task.

I can:

S.no	**Question**	
1	State the characteristics of microorganisms	☐

2	Describe the prevention and treatment mechanisms of diseases caused by microorganisms	
3	Explain different groups of microorganisms	
4	Explain diseases caused by microorganisms	
5	Discuss the importance of microorganisms in industry and the environment	

Unit: 2, <u>Assignment Questions -2</u>

Instruction: Dear learner, this is a written assignment to be submitted to your tutor and it is part of the formal assessment. Thus, pay significant attention while doing it.

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

a. Which of the following is present in both gram-positive and gram negative cell walls?
   a. an outer membrane b. peptidoglycan c. teichoic acid d. lipopolysaccharides

b. Bacterial endospore function in,
   a. Reproduction b. protein synthesis c. survival d. storage

c. Bacterial arrangement in packets of eight cells is described as a----------------------.
   a. micrococcus b. tetrad c. diplococcus d. sarcina

d. Archaea differ from bacteria on the basis of,
   a. structure of envelope b. size c. the archaea having a nucleus d. type of locomotor structures

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

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

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

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

Part II: Fill in the Blank Spaces

1) The bacterium that causes syphilis is called ________.
2) Bacteria in the genus *Rhodospirillum* that use hydrogen for oxidation and fix nitrogen are ________ bacteria.
3) *Streptococcus* is the ________ of bacteria that is responsible for many human diseases.
4) The length of the branches of the evolutionary tree characterizes the evolutionary ________ between organisms.
5) The deeply branching bacteria are thought to be the form of life closest to the last universal ________ ________.
6) Nonseptate hyphae are also called _________.
7) Unicellular fungi are called _________
8) Some fungi have proven medically useful because they can be used to produce _________.
9) A virus that infects a bacterium is called a/an ___________________.
10) A/an __________ virus possesses characteristics of both a polyhedral and helical virus
11) A virus containing only nucleic acid and a capsid is called a/an ___________________ virus or __________________ virus.
12) Viruses can be diagnosed and observed using a(n) _____________ microscope.

Attention

Short Answer

1. Which genera of fungi are common dermatophytes (fungi that cause skin infections)?
2. What is a dikaryotic cell?
3. Discuss the geometric differences among helical, polyhedral, and complex viruses.
4. Briefly explain the various methods of culturing bacteria and fungi.
5. Does a prion replicate? Explain.
6. What are kinetoplastids?
7. Aside from a risk of birth defects, what other effect might a toxoplasmosis infection have?
8. What is the function of the ciliate macronucleus?

Answer key for- Unit Assessment (Review Question)

1	**C**	5	**C**	9	**A**
2	**D**	6	**D**	10	**A**
3	**C**	7	**B**	11	**C**
4	**B**	8	**A**	12	**C**

Unit 2

Activity and Self-Test Answer Key

Unit 2. Microorganisms

Section 2.1. (WHAT ARE MICROORGANISMS?)

Self-Test Multiple Choice (Answers)

- 1. A, 2. B, 3. A, 4. B, 5. A

Section 2.2. (TYPES OF MICROORGANISMS)

Self-Test Multiple Choice (Answers)

- 1. A, 2. B, 3. C, 4. C, 5. D

Section 2.3. (EUBACTERIA)

Self-Test Essay (Answers)

- Bacteria exhibit a variety of shapes, and these shapes are influenced by several factors related to their survival and function. Here are the main reasons for the diversity in bacterial shapes:

- **Nutrient Uptake**: The shape of a bacterium can affect how efficiently it acquires nutrients. Different shapes may be favored under various nutritional conditions.
- **Motility**: The ability to move can impose selective pressure on the shape of bacteria. For example, rod-shaped bacteria with certain length-to-width ratios may move faster, and spiral-shaped bacteria can navigate through viscous environments more effectively.
- **Predation:** Bacteria have evolved different shapes as a defense against predators, contributing to the wide variety of forms observed today.

The bacterial cell wall and cytoskeleton play a crucial role in determining shape, which in turn influences critical functions such as nutrient acquisition, attachment to surfaces, swimming through liquids, and escaping predators. The diversity in bacterial morphology is a result of adaptive pressures optimizing their fitness for specific biological functions.

- The chemical composition of the nucleoid and cytoplasm in a bacterial cell is quite distinct:

Nucleoid:

- **DNA**: Approximately 60% of the nucleoid is DNA1.
- **RNA**: Around 30% is RNA.
- **Proteins:** The remaining 10% consists mostly of proteins, including RNA polymerase.

Cytoplasm:

- **Water:** About 80% of the bacterial cytoplasm is water.
- **Macromolecules:** This includes proteins, DNA, and RNA molecules.
- **Small Molecules**: Such as precursors to macromolecules and vitamins.
- **Inorganic Ions**: Various ions are also present.
- **Cytoplasmic Inclusions:** These are storage materials that can include glycogen, polyphosphate granules, and sulfur globules.

The cytoplasm also contains the cytosol, which is the liquid portion not enclosed within a membrane-bound component, composed of water, salts, and organic molecules. The cytoplasmic membrane, which encloses the cytoplasm, is made up of a phospholipid bilayer and may contain hopanoids and various fatty acids.

Activity 2.1. (Answer)

Here is a short note on the structure and function of flagella and pili in bacteria:

Flagella are long, whip-like appendages that extend from the cell membrane of bacteria and are primarily used for locomotion. They are composed of the protein flagellin and are anchored to the cell by a basal body. The rotation of the flagella propels the bacterium through its environment, allowing it to move towards nutrients or away from harmful substances.

Pili, also known as fimbriae, are shorter, hair-like structures that extend from the surface of bacterial cells. Unlike flagella, pili are not primarily used for movement but for adhesion to surfaces and other cells. This adhesion is crucial for colonization, biofilm formation, and the infection process. Some types of pili, such as sex pili, are involved in the transfer of genetic material during bacterial conjugation.

Table 1: Here is a table comparing the two structures

Feature	**Flagella**	**Pili**
Primary Function	Locomotion	Adhesion and conjugation
Composition	Made of flagellin	Made of pilin
Length	Longer, can be several times the length of the cell	Shorter, often less than the length of the cell
Visibility	Visible under electron microscope without staining	Visible under electron microscope without staining

Flexibility	Rigid and rotates like a propeller	Less rigid and primarily static
Location on Cell	Can be at one or both ends, or all over the cell surface	Evenly distributed or localized to poles
Types	Monotrichous, lophotrichous, amphitrichous, peritrichous	Fimbriae, sex pili, type IV pili

Activity 2.1. (Answer)

Eukaryotic microorganisms with cell walls include various groups, each with distinct types of cell walls:

- **Fungi:** Their cell walls are primarily composed of chitin, a strong but flexible nitrogen-containing polysaccharide.
- **Plants:** Plant cell walls are mainly made of cellulose, a rigid and robust polysaccharide that provides structural support.
- **Algae:** Algal cell walls can be composed of various substances, including cellulose, glycoproteins, or a combination of both.
- **Protists:** Some protists have cell walls made of cellulose, silica, or calcium carbonate, depending on the species.

The cell wall serves several functions in these organisms, such as providing structural support, maintaining cell shape, protecting against mechanical damage, and preventing osmotic lysis. In fungi, the chitin-based cell wall is crucial for maintaining the integrity and shape of the cells. In plants, the cellulose cell wall not only supports the plant structurally but also plays a role in controlling the direction of growth. Algal cell walls can vary greatly but often provide protection and contribute to the form of the algae. Protists with cell walls use them for protection and to maintain their shape, though the composition can greatly vary among different types of protists.

These cell walls are essential for the survival of these organisms, allowing them to thrive in various environments. Each type of cell wall is uniquely adapted to the needs of the organism it supports, reflecting the diversity and adaptability of eukaryotic microorganisms. The study of cell walls can provide insights into the evolutionary adaptations that have allowed these organisms to colonize a wide range of habitats.

Self-Test True or False (Answers)

- 1. False, 2. True, 3. True, 4. False, 5. True

Self-Test True or False (Answers)

- 1. False, 2. True, True, False, 5. True

Self-Test Essay (Answer)

The Gram stain procedure differentiates bacteria based on their cell wall composition through a series of staining steps. Here's how it works:

- **Primary Stain (Crystal Violet)**: All bacteria are stained with crystal violet, which turns them purple.
- **Mordant (Iodine):** Iodine is applied, forming a crystal violet-iodine complex inside the cell walls.
- **Decolorization (Alcohol or Acetone):** This step is critical. Alcohol or acetone is used to wash the slide. Gram-positive bacteria, with their thick peptidoglycan layer, retain the crystal violet-iodine complex and remain purple. In contrast, the thinner peptidoglycan layer of Gram-negative bacteria cannot retain the complex and the color is washed out, making them colorless.

- **Counterstain (Safranin):** A red dye, safranin, is applied. Gram-negative bacteria, now colorless, pick up this stain and turn pink or red, while Gram-positive bacteria remain purple.

The result is that Gram-positive bacteria appear purple under the microscope, and Gram-negative bacteria appear pink or red12. This differentiation is crucial in microbiology for bacterial identification and informs decisions about appropriate antibiotic treatment.

<u>Self-Test Matching (Answers)</u>

- 1. A, 2. B, 3. A, 4. B, 5. B, 6. A, 7. B

B). Sexual reproduction in bacteria

<u>Self-Test Multiple Choice (Answers)</u>

- 1. B, 2. B, 3. B, 4. C

Section 2.4. (ARCHAEA BACTERIA)

<u>Self-Test True or False (Answers)</u>

- 1. True, 2. True, 3. False, 4/ True

Physical factors that affecting microbial growths

<u>Self-Test True or False (Answers)</u>

- 1. True, 2. True, 3.False

Section 2.5. (<u>Fungi</u>)

Self-Test - Fill in the Blank (Answers)

- 1. Eukaryotic, 2. Mycelium

<u>Self-Test – Essay (Answers)</u>

- **Yes,** fungi offer a range of benefits for humans. Here are some of their key importances:
  - **Nutrient Cycling**: Fungi transform nutrients in a way that makes them available for plants. They break down plant and animal debris, cycling nutrients and increasing their availability in the soil.

- **Carbon Cycling and Climate Regulation**: Fungi contribute to soil carbon stock and play a major role in the carbon cycle, helping with soil health and carbon sequestration. This process captures carbon from the atmosphere and stores it in the soil, which can help reduce atmospheric carbon levels.
- **Nutrition and Food Security**: Many mushrooms are rich in vitamins, fiber, minerals, and protein, making them a nutritious food source and a good substitute for meat in various diets.
- **Health Benefits:** Fungi produce antibiotics like penicillin, which have saved countless lives. They can also be genetically engineered to produce insulin and other human hormones.
- **Environmental Benefits**: Fungi are an integral part of soil biodiversity and help tackle global challenges like climate change and hunger due to their role in vegetation and nutrient cycling.

These are just a few examples of how fungi are beneficial to humans and the environment.

- Fungi are incredibly adaptable and can be found in a wide variety of environments around the globe. Here's where different fungal groups typically grow in nature:
  - **Terrestrial Habitats**: Most fungi are terrestrial and thrive in temperate and tropical areas. They often grow in soil rich in organic matter, which is an ideal habitat for many species.
  - **Extreme Environments**: Some fungi can live in harsh conditions, such as the Arctic and Antarctic regions, usually as part of lichens1.
  - **Aquatic Environments**: Aquatic fungi usually inhabit clean, cool fresh water, though some species are found in slightly brackish water, and a few thrive in highly polluted streams.
  - **Parasitic Existence**: Some fungi are parasites on plants or animals and live on or within their hosts for at least part of their life cycle.

As for how fungi get their nutrients, they have several methods:

1) **Saprotrophic Fungi**: These fungi obtain energy from dead organic matter like dead plants and animals, breaking down the material and absorbing the nutrients.
2) **Parasitic Fungi:** These fungi feed on living organisms, often causing disease, and absorb nutrients directly from their hosts.
3) **Symbiotic Relationships**: Some fungi form mutualistic relationships with other organisms, such as the lichen, which is a symbiosis between fungi and algae. The fungi provide a structure for the algae, and in return, the algae supply carbon through photosynthesis.

Fungi play a crucial role in ecosystems as decomposers and nutrient recyclers, and their diverse methods of obtaining nutrients reflect their adaptability to different environments.

- Fungi play a crucial role in nutrient cycling and maintaining soil health, which are vital components of sustainable ecosystems. Here's how:
    - **Decomposition**: Saprophytic fungi break down dead organic matter, such as fallen leaves, dead trees, and other plant debris. This process releases nutrients that are locked within this organic matter, making them available for other organisms.
    - **Soil Structure:** By decomposing organic matter, fungi contribute to the formation of humus, a rich, organic component of soil that is essential for retaining moisture and nutrients. This improves soil structure and fertility, supporting plant growth and biodiversity.
    - **Nutrient Availability**: Fungi produce a wide variety of extracellular enzymes that help in decomposing complex molecules. This decomposition regulates the balance of carbon, nitrogen, and other nutrients in the soil, making them accessible to plants.

- **Bioremediation:** Some saprophytic fungi can absorb and immobilize harmful pollutants, including heavy metals, thereby cleaning up contaminated soils and water bodies.
- **Carbon Sequestration**: By breaking down organic matter, fungi play a significant role in the carbon cycle. They help sequester carbon in the soil, which is a critical process in mitigating climate change4.
- **Symbiotic Relationships**: Mycorrhizal fungi form mutualistic associations with plant roots, enhancing the plants' uptake of water and nutrients, particularly phosphorus and nitrogen, which are essential for plant growth.

In summary, the saprophytic activities of fungi are integral to ecosystem sustainability. They not only recycle nutrients, making them available for plant growth, but also improve soil health and contribute to the overall functioning and resilience of ecosystems.

- Pathogenic fungi have developed sophisticated mechanisms to infect host organisms, which can have significant implications for both agriculture and human health. Here's an analysis of these mechanisms and their implications:

  Mechanisms of Infection by Pathogenic Fungi:

  1) **Adhesion:** Fungi initiate infections by adhering to host cells through specific interactions between fungal adhesins and host cell receptors.
  2) **Invasion**: After adhesion, fungi may invade host cells directly or indirectly, breaching the host's physical barriers.
  3) **Nutrient Acquisition**: Competing for nutrients is crucial for fungal pathogens. They secrete enzymes to break down host tissues and absorb the released nutrients.

4) **Immune Evasion:** Pathogenic fungi have strategies to resist and evade host immune defenses, including phagocytosis and adaptive immune responses.

Implications for Agriculture:

- **Crop Loss**: Fungal diseases cause significant crop yield losses annually, which is a major challenge in achieving global food security.
- **Economic Impact**: The economic impact includes direct crop or yield loss, decreased quality of plant products, and costs of control measures like fungicide application.
- **Resistance Development**: The use of fungicides in agriculture can lead to the development of resistant fungal strains, making future control more difficult.

Implications for Human Health:

- **Disease Burden**: Fungal diseases contribute to morbidity and mortality, with some fungi causing systemic infections that can be life-threatening.
- **Antifungal Resistance**: Similar to antibiotic resistance, antifungal resistance is a growing concern, making infections harder to treat.
- **Allergies and Asthma:** Exposure to fungi can cause health problems like asthma and allergies, particularly in sensitive individuals.

In summary, the mechanisms by which pathogenic fungi infect hosts are complex and multifaceted, involving adhesion, invasion, nutrient acquisition, and immune evasion. The implications of fungal diseases are far-reaching, affecting agricultural productivity and posing health risks to humans. Addressing these challenges requires a multifaceted approach, including improved disease management in agriculture and the development of new antifungal treatments for human health.

- Fungi have a variety of reproductive strategies, both asexual and sexual, which allow them to adapt and survive in diverse environments.

Asexual Reproduction in Fungi:

1) **Fragmentation**: Pieces of the fungal body (hyphae) break off and grow into new individuals.
2) **Budding:** Common in yeast, a small part of the cell bulges out and eventually separates to form a new organism.
3) **Spore Formation**: Fungi produce spores that can be released and germinate into new fungi. These spores can be produced inside a sac-like structure called a sporangium or externally as conidia.

Sexual Reproduction in Fungi:

1) **Plasmogamy**: The fusion of cells from two different fungal strains brings together two haploid nuclei in the same cell.
2) **Karyogamy:** The haploid nuclei fuse to form a diploid nucleus.
3) **Meiosis:** The diploid nucleus undergoes meiosis to produce haploid spores, which can then germinate into new fungi.

Reproduction in Lichenized Fungi: Lichenized fungi, which are symbiotic associations between a fungus and a photosynthetic partner, also reproduce in various ways:

1) **Asexually:** Through the production of structures like soredia or isidia, which are small parts of the lichen thallus that contain both fungal and algal cells and can grow into new lichens.
2) **Sexually:** By producing ascospores that must find a compatible photosynthetic partner to form a new lichen.

These reproductive strategies contribute to the resilience and ecological success of fungi, including lichenized forms. They allow fungi to colonize new areas, adapt to changing environments, and maintain genetic diversity within populations.

<u>Self-Test True or False (Answers)</u>

- 1. False, 2. True

Reproduction in fungi

<u>Self-Test Fill in the Blank (Answers)</u>

- 1. Sexual, asexual, 2. Spores, 3. gametes, 4. hyphae & rhizoids

Harmful aspects of Fungi

<u>Self-Test Fill in the Blank (Answers)</u>

- 1. Antibiotics, 2. Nutrients, 3. mushrooms, truffles, 4. yeasts, molds, 5. ringworm, rusts.

Section 2.6. (<u>Protozoan</u>)

<u>Self-Test Multiple Choice (Answers)</u>

- 1. B, 2. A, 3. C, 4. A.

<u>Activity 2.3. Essay (Answer)</u>

1. Protists are mostly unicellular and belong to the kingdom Protista. They are eukaryotic, meaning they have a well-defined nucleus and membrane-bound organelles. Protists can be either autotrophic or heterotrophic and are primarily aquatic.

   Bacteria are unicellular and belong to the kingdom Monera. They are prokaryotic, which means they lack a nucleus and membrane-bound organelles. Bacteria can be found in virtually every environment and can be autotrophic or heterotrophic. They reproduce asexually through binary fission.

   Both protists and bacteria can be pathogenic, but their cellular structures and life processes are quite different. Understanding these differences is important for the treatment of diseases they may cause and for ecological studies. Protists include a wide variety of organisms, such as algae, amoebas, and slime molds, while bacteria include well-known groups like *E. coli* and *Streptococcus.*

Reproduction in protozoa

Self-Test True or False (Answers)

- 1. True, 2. False, 3. False, 4. True, 5. False.

Self-Test Fill in the Blank (Answers)

- 1. Saprozoic, 2. Parasitic

Self-Test Essay (Answer)

Protozoa, being diverse unicellular eukaryotic organisms, exhibit various types of nuclei and vacuoles that serve different functions:

Types of Nuclei in Protozoa:

- **Vesicular Nucleus**: Typically spherical or oval, containing a central body (endosome or nucleolus) surrounded by nuclear sap.
- **Compact Nucleus:** Contains a higher concentration of chromatin material.
- **Macronucleus (Somatic Nucleus):** A larger nucleus responsible for the general functioning of the cell. It is often polyploid, containing multiple copies of chromosomes.
- **Micronucleus (Germinal Nucleus):** A smaller nucleus involved in sexual reproduction and typically diploid.

Types of Vacuoles in Protozoa:

- **Contractile Vacuoles**: Help maintain osmotic balance by expelling excess water from the cell. They are especially important in freshwater protozoa.
- **Food Vacuoles**: Involved in the digestion of food. Enzymes break down the ingested food particles within these vacuoles.
- **Storage Vacuoles**: Store nutrients and other substances required by the cell.

These structures are essential for the survival and reproduction of protozoa, allowing them to adapt to various environmental conditions and nutritional availability. The diversity in the types of nuclei and vacuoles reflects the complexity and adaptability of protozoan life forms.

Self-Test Essay (Answers)

1. Babesia and Theileria are both genera of parasites that belong to the phylum Apicomplexa. They are known for infecting red blood cells and are transmitted by ticks, but they have distinct characteristics and implications for their hosts.
   - **Babesia:**
     - Babesia are protozoan parasites that infect the red blood cells of various animals, including humans.
     - They cause a disease known as babesiosis, which can present with symptoms such as fever, chills, and anemia.
     - The infection is typically transmitted through tick bites, particularly by the Ixodes species.
     - Diagnosis is usually made through blood tests, and treatment includes antiparasitic drugs like atovaquone and azithromycin or clindamycin and quinine.
     - In severe cases, an exchange transfusion might be necessary to replace the infected blood with fresh donor blood.
   - **Theileria:**
     - Theileria species are also tick-borne parasites that infect the blood cells of their hosts, primarily affecting cattle and other livestock.
     - They cause diseases such as tropical theileriosis and East Coast fever, which can be severe and lead to high mortality rates in affected animals.
     - Theileria parasites undergo a complex life cycle involving both mammalian and tick hosts. They are known to induce transformation of infected cells of lymphocyte or macrophage/monocyte lineages in their mammalian hosts.
     - Control and prevention of Theileria infections often involve tick control measures and, in some regions, vaccination.

   Both Babesia and Theileria are significant due to their impact on animal health and agriculture. In some cases, Babesia can also affect human health, leading to the need for awareness and preventive measures in areas where these parasites are prevalent
2. The common species of Plasmodium in Ethiopia are ***Plasmodium falciparum* and *Plasmodium vivax***. These two species are the most widely distributed and well-known malaria-causing parasites in the country, with ***P. falciparum*** being responsible for the majority of malaria cases. Additionally, other species such

as ***Plasmodium ovale, Plasmodium malariae***, and ***Plasmodium knowlesi*** have also been reported but are less common.

3. **Nagana**, also known as **Gendi** in some regions, is a disease primarily affecting animals and is caused by several species of protozoan parasites of the genus Trypanosoma. The most common causative agents of Nagana are ***Trypanosoma congolense***, ***Trypanosoma vivax***, and to a lesser extent, ***Trypanosoma brucei brucei***.

   The disease is transmitted by the bite of infected tsetse flies (**genus Glossina**), which serve as the vector for **Nagana**. These flies are found in sub-Saharan Africa and are the primary means of transmission of the Trypanosoma parasites from one animal to another. **Nagana** has a significant impact on livestock health and agriculture, causing symptoms such as fever, weakness, and anemia, which can lead to decreased productivity and even death in severe cases.

4. Leishmania spp. are protozoan parasites that cause the disease leishmaniasis. The vector and life cycle of Leishmania spp. are as follows:
   - **Vector:** The vector for Leishmania spp. is the female phlebotomine sandfly. These tiny insects transmit the parasites to humans and other mammals through their bites1.

   Life Cycle:

   1) **Infection**: The life cycle begins when an infected **sandfly** bites a host, injecting the infective stage, known as promastigotes, into the skin.
   2) **Inside the Host**: The promastigotes are phagocytized by macrophages and other types of mononuclear phagocytic cells at the site of the bite.
   3) **Transformation**: Inside these cells, promastigotes transform into amastigotes, the tissue stage of the parasite, which multiply by simple division.
   4) **Spread:** Amastigotes infect other mononuclear phagocytic cells, spreading the infection.
   5) **Transmission**: When a sandfly bites an infected host, it ingests the amastigotes along with the blood meal.
   6) **In the Sandfly**: Inside the **sandfly's** gut, amastigotes transform back into promastigotes, develop, and migrate to the proboscis, ready to infect a new host.

   The disease can manifest in different forms, including cutaneous, visceral, and **mucocutaneous leishmaniasis**, depending on the Leishmania species and the host's immune response. The clinical management and treatment of leishmaniasis can vary based on the species involved and the form of the disease.

Section 2.7. (**Viruses**)

Self-Test Essay (Answers)

1. Viruses and cells are fundamentally different in several ways. Here's a summary of the key differences:
    - **Living Status**: Cells are considered living organisms as they can survive independently, while viruses cannot survive without a host and are often considered non-living.
    - **Reproduction**: Cells reproduce through processes like binary fission, mitosis, or meiosis. Viruses, on the other hand, need to infect host cells to replicate.
    - **Genetic Material**: Cells have a complete set of genetic material, which can be DNA or RNA. Viruses have only partial genetic information and may contain either DNA or RNA.
    - **Structure**: Cells have a complex structure with a cell wall, ribosomes, and other organelles. Viruses lack these structures and are generally composed of just a protein coat and genetic material.
    - **Size**: Cells are generally larger than viruses, which are submicroscopic and require an electron microscope to be seen.

Cells are the basic unit of life, present in all living beings, and can perform all the functions necessary for life. Viruses, however, are considered infectious agents that can only replicate by attaching themselves to cells. They are much simpler and cannot carry out life processes on their own.

2. A virus needs a host cell because it lacks the necessary cellular machinery to replicate on its own. Here's a more detailed explanation:
    - **Replication**: Viruses can only reproduce by infecting a host cell and using its machinery to make more viruses.

- **Energy and Resources**: Viruses cannot capture or store energy themselves; they rely on the host for energy and the raw materials needed to create new virus particles.
- **Genetic Instructions:** After attaching to a host cell, a virus inserts its genetic instructions, which are then used by the host's cellular processes to assemble new viruses.

  In essence, viruses are parasitic entities that depend entirely on a host cell to carry out the functions necessary for their reproduction and survival. Without a host, viruses are inert particles.

3. Viral genomes are quite unique compared to cellular genomes, and here are some of their unusual characteristics:

- **Size and Complexity**: Viral genomes vary greatly in size, ranging from a few thousand to over a million base pairs. This is unlike cellular genomes, which are typically larger and more complex.
- **Genetic Material:** Viruses can have either DNA or RNA as their genetic material, which is not the case for cells that contain DNA. This diversity significantly influences how viruses reproduce.
- **Coding Density:** Some viruses, like the polydnavirus, have an extremely low coding density and do not encode DNA-replication proteins, which is unusual compared to the more complex cellular genomes.
- **Gene Content:** Certain giant viruses, such as Mimivirus, have genomes that encode a large number of proteins, including some associated with transcription, translation, and replication machinery, which are typically not found in viruses.
- **Redundancy:** The complexity landscape of viral genomes shows that double-stranded DNA viruses are, on average, the most redundant, while single-stranded DNA viruses are the least. This contrasts with the more streamlined and less redundant genomes of cells.

These features challenge our traditional view of viruses and have implications for understanding their evolution and interactions with host cells.

Self-Test Fill in the Blank (Answers)

- 1. Capsid, 2. DNA or RNA, 3. Enveloped, 4. Replication, 5. Receptors or spikes

Activity 2.4. (Answer)

Bacteriophages, commonly known as phages, can initiate an infection in their bacterial host cells through two main approaches:

(1). Lytic cycle

- The Lytic Cycle: In this approach, the phage infects a bacterium, takes over the host cell's machinery to produce more phages, and eventually causes the bacterium to burst (lyse), releasing new phage particles1.

(2). Lysogenic cycle

- The Lysogenic Cycle: Here, the phage integrates its DNA into the bacterial chromosome. The phage DNA, now termed a prophage, is replicated along with the host cell's DNA and can remain dormant until it is induced to enter the lytic cycle1.

These cycles represent the fundamental strategies by which bacteriophages propagate and spread within bacterial populations.

Difference between DNA & RNA Viruses

Self-Test Essay (Answers)

1. Viruses come in various shapes, and here are some of the common ones:
    - Spherical
    - Rod-shaped
    - Brick-shaped
    - Tadpole-shaped
    - Bullet-shaped
    - Filament
2. Viruses play a complex role in relation to humans and the environment. While they are often associated with diseases, they also have beneficial aspects:
    - **Microbiome Balance:** Some viruses are part of the human microbiome and help maintain the balance of bacteria in our bodies.

- **Medical Treatments:** Viruses can be engineered to treat diseases, deliver vaccines, and diagnose infections.
- **Gene Therapy**: They have been used in gene therapy to introduce new genes into cells to treat genetic disorders.
- **Research Tools:** Viruses serve as valuable tools in biological research to understand cellular mechanisms and develop new drugs.
- **Evolution:** Viral genetic material incorporated into human DNA over millions of years has played a role in the development of our reproductive and nervous systems.

Therefore, while viruses can cause harm, they also contribute significantly to health, science, and the ecosystem. Their presence is indeed essential in various ways.

3. **Check the sub title**: **Phages exhibit two different types of life cycle, on your module.**

CLASSIFICATION OF VIRUSES

<u>Self-Test Essay (Answers)</u>

1. Animal and bacterial viruses have different methods of entering their hosts due to the structural differences between animal cells and bacterial cells. Here's a contrast of their entry mechanisms:

Animal Viruses:

- **Receptor-Mediated Endocytosis**: Many animal viruses enter cells through this process, where the virus binds to a receptor on the cell surface and is then engulfed into an endocytic vesicle.
- **Fusion:** Enveloped viruses can fuse their membrane with the host cell membrane, releasing the viral capsid into the cell's cytoplasm.

Bacterial Viruses (Bacteriophages):

- **Direct Penetration**: Bacteriophages often inject their genetic material into the bacterial cell, leaving the capsid outside.
- **Receptor Binding**: They attach to specific receptors on the bacterial surface, which triggers the injection of the viral genome into the bacterial cell.

These mechanisms reflect the viruses' adaptation to their specific hosts' cellular structures and processes. Animal cells, being eukaryotic, have a more complex cell structure and internal organelles, while bacterial cells, being prokaryotic, have a simpler structure without an internal membrane system, which influences how viruses must enter to initiate infection.

2. Persistent and latent viral infections are two types of long-term infections, but they have distinct characteristics:
   - **Persistent Viral Infection**: In this type of infection, the virus is continually present in the body. The infected individual may or may not show symptoms, but the virus can be detected at all times. Diseases like hepatitis B and C are examples of persistent viral infections.
   - **Latent Viral Infection**: A latent viral infection is one where the virus remains in equilibrium with the host for long periods without causing symptoms. The virus is essentially dormant and cannot be detected until it is reactivated, which can be triggered by various factors like stress or a weakened immune system. Herpes simplex virus (HSV) and varicella-zoster virus (VZV), which causes chickenpox and shingles, are examples of viruses that can establish latent infections.

   In summary, the key difference is that in persistent infections, the virus is continuously active at some level, while in latent infections, the virus lies dormant and undetectable until reactivation occurs.

3. Viral infections in plants and animals differ in several ways due to the distinct cellular structures and defense mechanisms in these organisms. Here’s a comparison:
    - **Cell Entry**: Animal viruses often enter through endocytosis or membrane fusion, as animal cells lack a rigid cell wall. Plant viruses usually enter through physical damage or via vectors like insects, as they need to bypass the plant cell wall.
    - **Genetic Material**: Plant viruses mostly have RNA genomes, which can be single or double-stranded. Animal viruses can have either DNA or RNA genomes, with more diversity in their structures.
    - **Transmission:** Plant viruses are often transmitted through vectors like insects or through grafting and mechanical damage. Animal viruses can be transmitted in various ways, including direct contact, bodily fluids, air, and vectors like mosquitoes.
    - **Host Range:** A single type of plant virus can often infect a wide range of plant species, whereas animal viruses tend to have a more specific host range due to the specificity of their surface proteins to receptors on host cells.
    - **Symptoms and Effects**: Plant viral infections can lead to symptoms like leaf curling, yellowing, and stunted growth. Animal viral infections can cause a wide range of symptoms, from mild to severe, affecting various body systems.
    - **Defense Mechanisms**: Plants use a defense mechanism called RNA silencing to degrade viral RNA, which is different from the immune responses seen in animals, which involve antibodies and cell-mediated immunity.

    These differences highlight the specialized adaptations viruses have developed to infect and propagate within their specific hosts.

Self-Test Essay (Answer)

1. Bacteriophages, often simply called phages, are viruses that infect and replicate within bacteria. They are among the most numerous and diverse entities in the biosphere. Phages have a simple structure, typically consisting of a protein shell (capsid) that encloses their genetic material, which can be either DNA or RNA, and often a tail structure used to inject their genetic material into the host bacteria.

In biotechnology, bacteriophages have a variety of applications due to their specificity to bacterial hosts and their ability to manipulate bacterial genetics:

- **Antibacterials**: Phages can be used as alternatives to antibiotics, especially for treating antibiotic-resistant bacterial strains.
- **Phage Display**: This technique uses phages to connect proteins with the genetic information that encodes them, useful for studying protein interactions and drug development.
- **Biocontrol Agents**: In agriculture, phages can be used to combat bacterial diseases in plants without harming beneficial organisms or the environment.
- **Vaccine Delivery**: Phages can serve as vehicles for DNA or protein vaccines, presenting antigens to the immune system.
- Phage Typing: This diagnostic method uses phages to detect pathogenic bacterial strains based on their susceptibility to specific phages.
- **Genetic Engineering**: Phages are used as cloning vectors in genetic engineering to introduce new genetic material into bacteria.

These uses highlight the potential of phages to contribute significantly to various fields, including medicine, agriculture, and environmental science.

COMMON VIRAL DISEASES IN ETHIOPIA

Self-Test Essay (Answer)

1. The attachment phase is crucial for virus-host specificity. Here's how it contributes to this specificity:
   - **Specific Binding:** Viruses have proteins on their capsid or glycoproteins embedded in their envelope that must bind to specific receptors on the host cell's surface.
   - **Host Range Determination**: This specific binding determines which hosts and even which cells within the host a virus can infect.
   - **Viral Entry:** After attachment, the virus can enter the host cell to begin replication, which is only possible if the initial attachment is successful.
2. A lysogen is a bacterial cell that harbors a prophage, which is the genetic material of a bacteriophage (a virus that infects bacteria) integrated into the host bacterium's genome1. The prophage remains latent and does not harm the host; it replicates along with the host's DNA when the bacterium divides.

A prophage is the dormant form of a bacteriophage's genome within a lysogen. It can be activated under certain conditions, leading to the production of new phages that may lyse the host cell and spread to infect other bacteria3. This lysogenic cycle allows the phage to persist in the host without immediately destroying it, contributing to the genetic diversity and evolution of bacterial populations.

3. Temperate and virulent (lytic) viruses differ primarily in their life cycles and interactions with the host:
   - **Temperate Viruses**: These viruses can undergo a lysogenic cycle where the viral DNA integrates into the host cell's genome and replicates along with it without causing immediate harm. The integrated viral DNA, known as a prophage, can remain dormant for extended periods. Under certain conditions, it can be induced to enter the lytic cycle.

- **Virulent (Lytic) Viruses:** Virulent viruses only undergo the lytic cycle, where they infect the host cell, take over its machinery to produce new virus particles, and ultimately cause the cell to lyse (burst), releasing the new viruses. This process results in the death of the host cell.

In essence, temperate viruses have the option to be dormant within the host, while virulent viruses are always active, leading to the destruction of the host cells.

Self-Test True or False (Answers)

- 1. True, 2. False, 3. True, 4. False, 5. False

Section 2.8. (**NORMAL MICROBIOTA**)

Self-Test Fill in the Blank (Answers)

- 1. Microbiome, 2. Skin, Mucosa, tracts, 3. Symbiotic, 4. Pathogenic, 5. Genetics

Self-Test Essay (Answers)

1. **Normal microbiota**, also known as resident microbiota, refers to the diverse collection of microorganisms that are regularly found in various parts of the human body, such as the skin, mouth, and gastrointestinal tract. These organisms are generally harmless and can be beneficial, aiding in processes like digestion and protecting against pathogenic microbes.

   Transient microbiota consists of microorganisms that temporarily reside on the body. They do not form a permanent part of the microbiome and can fluctuate due to various factors such as hygiene and diet. Transient microbiota may include pathogenic organisms, but they are typically unable to establish themselves long-term due to competition from resident microbiota.

2. Normal and transient microbiota differ from opportunistic microorganisms in their relationship with the host and the circumstances under which they can cause disease.

- **Normal microbiota** are the microorganisms that permanently reside in certain body sites and are typically harmless or beneficial under normal circumstances. They can outcompete potential pathogens and contribute to the host's immune system functioning.
- **Transient microbiota are** the microorganisms that temporarily inhabit the body. They do not establish permanent residence and are influenced by factors like hygiene. While they can include pathogens, they usually do not cause disease due to the presence of the normal microbiota.
- **Opportunistic microorganisms,** on the other hand, are usually non-pathogenic and live in or on the host without causing disease. However, under certain conditions, such as when the host's immune system is compromised, these organisms can become pathogenic and cause disease. Opportunistic pathogens can include bacteria, fungi, viruses, and protozoa, and they take advantage of weakened defenses to establish infections, which can be serious or even life threatening.

In summary, while normal and transient microbiota are part of the regular microbial community of the body, opportunistic microorganisms are those that seize the chance to cause disease when the body's defenses are down.

3. Normal microbiota and infectious diseases are differentiated by their roles and impacts on the human body:

Normal Microbiota:

- Comprises bacteria, fungi, and archaea that are regularly found on the body's surfaces and within certain internal environments.
- Generally harmless and often beneficial, contributing to functions like digestion and immune system support.
- Maintain a symbiotic relationship with the host, where both the host and the microbiota benefit from each other.

Infectious Disease:

- Results from the invasion and multiplication of pathogenic microorganisms in the body.
- Causes harm by disrupting normal physiological functions or systems.
- Can be caused by various pathogens, including bacteria, viruses, fungi, and parasites that are not typically part of the normal microbiota.

In essence, while normal microbiota are a stable part of the body's ecosystem and contribute to its health, infectious diseases are caused by foreign pathogens that disrupt this balance and cause harm.

Activity 2.5 (Answer)

Germ Theory of Disease

The germ theory of disease is a fundamental scientific principle that attributes the cause of many diseases to microorganisms. These tiny life forms, which include bacteria, viruses, fungi, and protozoa, are often invisible to the naked eye but can be observed with the aid of a microscope. The theory posits that these pathogens invade the human body, reproduce, and disrupt normal bodily functions, leading to illness.

Historically, the germ theory represented a monumental shift in understanding diseases. Prior to its acceptance, many believed in the miasma theory, which blamed diseases on "**bad air**" from decomposing materials. The germ theory, developed in the 19th century, owes much to the work of scientists like **Louis Pasteur and Robert Koch**. Pasteur's experiments debunked the idea of spontaneous generation and demonstrated that microorganisms could cause fermentation and disease. Joseph Lister applied these findings to develop antiseptic techniques in surgery, drastically reducing infections.

The germ theory has had profound implications for public health, leading to practices such as sterilization, vaccination, and antibiotics, which have saved countless lives.

Koch's Postulates

Koch's postulates are a set of four criteria established by Robert Koch to determine whether a specific microbe causes a disease. They are as follows:

- The microorganism must be found in abundance in all organisms suffering from the disease, but not in healthy organisms.
- The microorganism must be isolated from a diseased organism and grown in pure culture.
- The cultured microorganism should cause disease when introduced into a healthy organism.
- The microorganism must be reisolated from the inoculated, diseased experimental host and identified as being identical to the original specific causative agent.

These postulates were revolutionary because they provided a scientific framework for linking specific microbes to specific diseases. Koch himself used these criteria to identify the bacteria responsible for tuberculosis and cholera. While modern science recognizes that there are exceptions to these rules, such as viruses that cannot be cultured or diseases caused by multiple pathogens, Koch's postulates remain a cornerstone in the study of infectious diseases. They have also inspired molecular versions that guide the identification of genes responsible for an organism's virulence.

In essence, Koch's postulates have laid the groundwork for the identification and treatment of infectious diseases, contributing significantly to the field of microbiology and medicine.

Section 2.9. (MODES OF DISEASE TRANSMISSION AND WAYS OF PREVENTION)

- 1. True, 2. False, 3. True, 4. False, 5. True

<u>Activity 2.6 (Answers)</u>

- Reservoir hosts are organisms that harbor parasites without being affected by the disease. They play a critical role in the life cycle of parasites by ensuring their survival and facilitating the transmission to other hosts, including humans.
- Reservoir hosts for diseases like leishmaniasis, which include certain wild and domestic animals, maintain the parasite within a population. Their presence in proximity to human settlements can increase the risk of transmission through vectors like sandflies.
- Controlling parasitic diseases is complicated by reservoir hosts because they often show no symptoms and can live in various environments. This makes it difficult to identify and target them in disease control programs, requiring comprehensive strategies that include vector control and public health measures.
- Understanding the complex interactions between parasites and their hosts, including reservoir hosts, is essential for developing effective treatments. It helps in identifying potential targets for intervention and understanding the mechanisms of disease transmission and pathology.
- Environmental changes, such as deforestation and urbanization, can alter the habitats of reservoir hosts, leading to increased contact with human populations and potentially higher rates of disease transmission. This underscores the need for environmental considerations in public health planning for parasitic diseases.

Section 2.10. (USES OF MICROORGANISMS)

AGRICULTURE

<u>Self-Test True or False (Answers)</u>

- 1. True, 2. False, 3. True.

BIOREMEDIATION

Self-Test Multiple Choice (Answers)

- 1. C, 2. B, 3. C

FOOD PRODUCTION AND PROCESSING

Self-Test Multiple Choice (Answers)

- 1. A, 2. B, 3. C, 4. D, 5. E.

THE PHOSPHORUS CYCLE

Self-Test Multiple Choice (Answers)

- 1. C, 2. D, 3. C.

Section 2.11. (**CONTROLLING MICROORGANISMS**)

Self-Test Multiple Choice (Answers)

- 1. A, 2. C, 3. B, 4. C.

Section 2.12. (BACTERIAL ISOLATION TECHNIQUES)

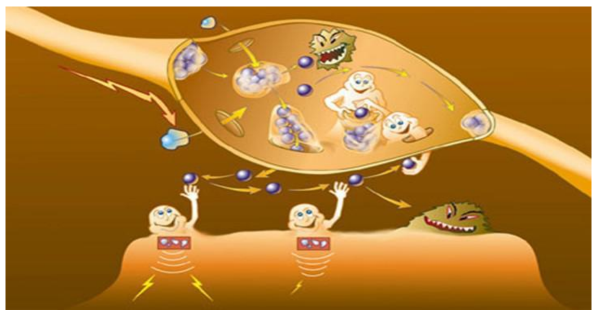
Section 2.23. Renowned Microbiologists in Ethiopia

Unit summary question

- 1. C, 2. D, 3. C, 4. B, 5. C, 6. D, 7. B, 8. A, 9. A, 10. A, 11. C, 12. C.

UNIT 3

Section 3: ENERGY TRANSFORMATION



INTRODUCTION

☸ **Dear learner**, do you know energy transformation? You are going to learn the exciting topic of energy transformation in the cells of living organisms. As you know, all living things require energy to carry out their essential functions, such as growth, reproduction, and movement. **ENERGY TRANSFORMATION** is the process of changing energy from one form to another. There are many different forms of energy, such as electrical, thermal, nuclear, mechanical, electromagnetic, sound, and chemical. Energy transformations occur everywhere every second of the day. For example, when you turn on a light bulb, electrical energy is transformed into light and heat energy. When you ride a bike, chemical energy in your muscles is transformed into mechanical energy that moves the pedals. When you eat food, chemical energy in the food is transformed into thermal energy that keeps your body warm. Energy transformations are important for understanding how things work and how to use energy efficiently and sustainably.

In this unit, you will explore how energy is transformed in the cells of living organisms through the process of cellular respiration. You will also learn about the different stages of cellular respiration, including glycolysis, the Krebs cycle, and oxidative phosphorylation. You will also review the role of ATP (adenosine triphosphate) in providing energy to cells.

Unit learning outcomes

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

• Discuss the process of energy transformation in cells.
• Summarize the process of photosynthesis using chemical equation.
• Analyze an absorption spectra of chlorophyll a and chlorophyll b using graph.
• Discuss the mechanism as to how CO_2 is fixed in C_3, C4 plants, and CAM Plants.
• Justify the reason why the rate of photorespiration is less in C4 plants as compared to C3 plants.
• Demonstrate whether or not organic molecules (such as starch) present in leaves.
• Discuss how energy is harvested during aerobic respiration.
• Differentiate between substrate-level phosphorylation and oxidative phosphorylation
• Show the mechanism electron transport system in mitochondria.
• Discuss the significances of fermentation by microorganisms in our daily life.
• Apply the concept of cellular respiration to calculate amount of energy yield from a given molecule of glucose.
• Justify how energy transformations in cells contribute for the maintenance CO2 and O_2 balance in the atmosphere.
• Appreciate the mechanism of energy transformation in cells.

Unit three study time: **(Allotted time 26 hrs)**

Table of contents

LEARNING STRATEGIES

For successful distance learning utilize the following strategies as needed for each lesson: mind mapping, mental rehearsal, short visits or onsite observations, comparing and contrasting, drawing and photographing real plants or animals, creating analogies, paraphrasing, using outlines and flow charts, taking brief notes, and underlining or highlighting key points.

SECTION 3.1. CELLULAR METABOLISM

INTRODUCTION

☸ **Dear learner**, you welcome to unit two of grade 12 biology, which reveals about cellular respiration. Cellular metabolism refers to the chemical reactions that occur in living cells to sustain life. These reactions involve the transformation of energy and molecules, such as carbohydrates, proteins, and fats, into usable forms for the cell. The process of cellular respiration is a key component of cellular metabolism, which involves the breakdown of glucose to produce ATP, the main energy source for cells. Other metabolic pathways include photosynthesis, which occurs in plants and some bacteria, and anabolic pathways, which involve the synthesis of complex molecules from simpler ones. Understanding cellular metabolism is essential for understanding how living organisms function and survive.

MINIMUM LEARNING COMPETENCIES

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

- Define cellular metabolism.
- Explain anabolic and catabolic pathways in cellular metabolism.
- Compare and contrast catabolism and anabolism

? What is metabolism?

Cellular metabolism is the sum of all the biochemical reactions that take place within a cell. It includes all the reactions involved in degrading food molecules, in synthesizing macromolecules needed by the cell, and in generating small precursor molecules, such as some amino acids, for cellular needs. Cellular metabolism is essential for life, as it provides energy and building blocks for various cellular processes.

Dear learner, do you know the types of metabolic pathways that cells use to obtain and use energy? **Very nice**! There are different types of metabolic pathways that cells use to obtain and use energy. Some of the most common ones are:

Cellular respiration: This is a process that breaks down glucose (a simple sugar) to produce ATP (adenosine triphosphate), which is the main energy currency of the cell. Cellular respiration involves four main steps: glycolysis, pyruvate oxidation, citric acid cycle, and oxidative phosphorylation. The overall equation for cellular respiration is:

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

Photosynthesis: This is a process that converts light energy into chemical energy stored in glucose. Photosynthesis occurs in plants, algae, and some bacteria. Photosynthesis involves two main stages: light-dependent reactions and light-independent reactions (also known as the **Calvin cycle**). The overall equation for photosynthesis is:

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

Other metabolic pathways: Depending on the type of organism and the environmental conditions, cells may use other metabolic pathways to obtain and use energy. For example, some prokaryotes (such as bacteria and archaea) can use different sources of carbon and energy, such as organic compounds, inorganic compounds, or sunlight. These pathways are classified as **heterotrophic, autotrophic, phototrophic, or chemotrophic.**

What is the difference between catabolism and anabolism?

Dear learner, read the table below carefully to understand the difference between catabolism and anabolism. After reading, try to memorize it by repeating it carefully. To memorize this table, you can use various strategies such as mnemonics, flashcards, or repetition. For example, you can remember that catabolism starts with C and so does breakdown and release, while anabolism starts with A and so does build up and require. You can also make flashcards with the terms on one side and the definitions on the other, and quiz yourself regularly. Alternatively, you can repeat the table out loud or write it down several times until you can recall it from memory.

Table 3.1. Comparison of anabolic and catabolic pathways

No.	Anabolism	Catabolism
1.	It is the constructive phase of metabolism.	It is the destructive phase of metabolism.
2.	It is the process whereby simpler substances are joined together to form complex macromolecules.	It is the process whereby complex macromolecules are broken down to form simpler substances or monomers.

3.	The process requires energy to construct substances.	The process releases energy as a result of the breakdown of molecules.
4.	It is an endergonic (energy-absorbing) reaction.	It is an exergonic (energy-releasing) reaction.
5.	It occurs during photosynthesis.	It occurs during cellular respiration.

Dear learner, organisms require a continuous supply of ATP, with the potential energy stored in food serving as the source to meet this need. Similarly, organisms' daily activities are fueled by the energy from the sun, and even on a cellular level nutrients cycle and energy flow (**see Figure 3.1**).

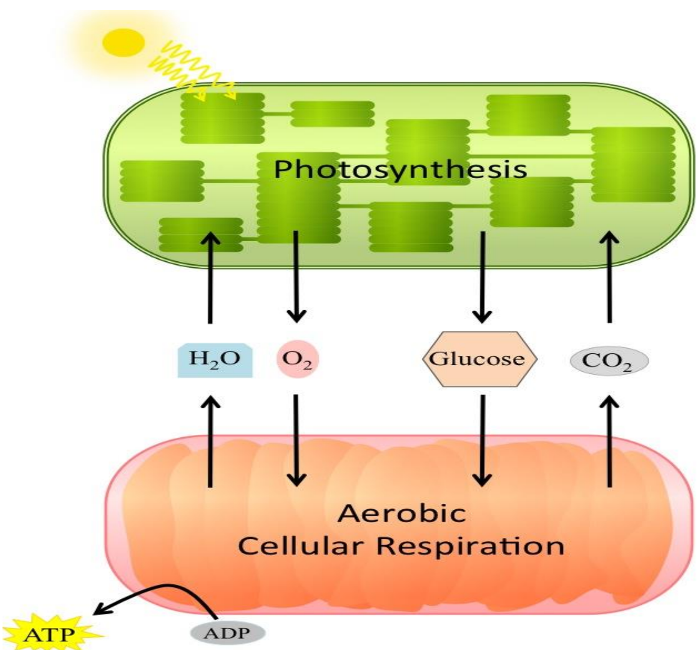


Figure 3.1. Metabolic pathways

Self-test

Cellular respiration uses glucose and oxygen, which have high levels of free energy, and releases Co_2 and water, which have low levels of free energy. Is cellular respiration spontaneous or not? Is it exergonic or endergonic? What happens to the energy released from glucose?

This image illustrates the relationship between **photosynthesis and cellular respiration**. Compounds generated in **photosynthesis** are used in cellular respiration, and vice versa. That means, all organisms need ATP, but not all organisms use the same pathways to generate ATP from the food that is consumed. Aerobic cellular respiration uses oxygen (**O_2**) and glucose to generate

ATP. Organisms (plants, animals, fungi and microbes) that live in an oxygen-rich environment use this process to generate **ATP**.

As the aerobic cellular respiration equation shows, an organism needs to acquire oxygen (**O_2**) to combine with glucose (**$C_6H_{12}O_6$**) in order to transfer the energy in glucose to ATP. In the process, carbon dioxide (**CO_2**) and water (**H_2O**) are given off as waste products.

Self-test

Choose the appropriate answer from the given alternatives

1. What is the name of the metabolic pathway that breaks down glucose into two molecules of pyruvate, producing a net gain of two ATP and two NADH?

   a) Glycolysis b). Krebs cycle c). Electron transport chain d). Fermentation

2. What are the three main types of metabolic reactions that occur in cells?

   a) Anabolism, catabolism, and amphibolism
   b) Oxidation, reduction, and hydrolysis
   c) Phosphorylation, dephosphorylation, and transphosphorylation
   d) Condensation, cleavage, and isomerization

3. What is the name of the molecule that acts as the main energy carrier in cells, storing and releasing energy in its phosphate bonds?

   a) ADP b). ATP c). AMP d). NAD+

4. What is the name of the process that transfers electrons from NADH and FADH2 to a series of protein complexes, generating a proton gradient across the inner mitochondrial membrane?

   a) Glycolysis b). Krebs cycle c). Electron transport chain d). Fermentation

5. What is the name of the enzyme that uses the proton gradient to synthesize ATP from ADP and Pi, coupling the exergonic electron transport with the endergonic ATP synthesis?

   a) ATP synthase b). ATPase c). ATP hydrolase d). ATP transferase

✓ **Self-evaluation check list**

Put a tick (√) against each of the following tasks, which you can perform. If you cannot perform any of these tasks, go back and read the lesson for that particular task.

I Can:

S.no	Questions	✓ Check
1	• Define cellular metabolism.	
2	• Explain anabolic and catabolic pathways in cellular metabolism.	
	• Compare and contrast catabolism and anabolism	

SECTION 3.2. PHOTOSYNTHESIS

INTRODUCTION

Dear learner, I hope you have a clear understanding of what cellular respiration is and its types from the above topic. In this topic, you will gain an adequate understanding of photosynthesis and the process of photosynthesis.

I wanted you to take a moment to think about photosynthesis, a fascinating biological process that is essential for life on Earth. Photosynthesis is the process by which plants, algae, and some bacteria convert light energy into chemical energy that can be used by living organisms. This process not only produces organic molecules such as sugars, starch, and cellulose, but also generates oxygen as a by-product.

As you can see, photosynthesis plays a critical role in sustaining life on our planet. It provides the oxygen we breathe and the food and fuel we need to survive. Understanding this process is crucial for anyone interested in biology.

I encourage you to explore this topic further and learn more about the amazing world of photosynthesis. Who knows, you may even discover something new and exciting that could help us better understand and protect our planet.

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

- Define photosynthesis.
- Explain the process of dark and light reaction of photosynthesis.
- Describe the external and internal structure of a leaf.
- Describe the different chlorophyll pigments involved in the absorption of light energy.
- Analyze an absorption spectra of the chlorophyll pigments from the graph.
- Explain the the roles of grana and and stroma in the process of photosynthesis.
- Describe cyclic and non-cyclic photophosphorylation.
- Show an absorption spectra of chlorophyll a and chlorophyll b using graph.
- Explain the process of Calvin cycle.
- Compare cyclic and non-cyclic photophosphorylation.
- Differentiate between C_3 , C_4 plants, and CAM Plants.
- Justify the reason why the rate of photorespiration is less in C4 plants as compared to C3 plants.
- Summarize the process of photosynthesis using chemical equation.
- Conduct an experiment to show the release of energy during photosynthesis.
- Conduct an experiment to show the presence of starch in green leaves.
- Explain the significances of photosynthesis.

? What is photosynthesis?

Dear learner, photosynthesis is a series of chemical reactions that use light energy to assemble **CO_2** into glucose (**$C_6H_{12}O_6$**) and other carbohydrates. The plant uses water in the process and releases oxygen gas (**O_2**) as a byproduct. The reactions of photosynthesis are summarized as follows:

$$\underset{\text{Carbon dioxide}}{6\,CO_2} + \underset{\text{Water}}{12\,H_2O} \xrightarrow[\text{Chlorophyll}]{\text{Light energy}} \underset{\text{Glucose}}{C_6H_{12}O_6} + \underset{\text{Oxygen}}{6\,O_2} + \underset{\text{Water}}{6\,H_2O}$$

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

🛠 **Self-test**

- Discuss the role of autotrophic organisms in establishing the base of food webs in various ecosystems and how they contribute to the flow of energy and matter through an environment.
- Examine the dependence of heterotrophic organisms on autotrophs for their energy needs and the implications of this relationship for the stability of ecosystems.
- Analyze the significance of photosynthesis in regulating global carbon cycles, focusing on how autotrophic processes impact atmospheric carbon dioxide levels and climate change.

2.2.1. External and Internal Structure of the Leaf

What is the role the outer structures of the leaf have?

Dear learner, the outer leaf layer is known as **the epidermis**. The epidermis secretes a waxy coating called the cuticle that helps the plant retain water. A leaf has three main parts– Leaf base, leaf lamina, and petiole (**Figure 3.2**). Epidermis is a continuous layer on the outside of the plant, one cell thick, that provides protection .In stems and leaves it is covered with a waxy cuticle which is waterproof and helps to protect the organ from drying out and from infection. In leaves, it also has pores called stomata, which allow entry of carbon dioxide for photosynthesis. The mesophyll is made up of specialized parenchyma cells found between the lower and upper epidermis of the leaf. They are specialized for photosynthesis and therefore contain chloroplasts. They are of two types, palisade mesophyll and spongy mesophyll. Spongy mesophyll is so-called because in three dimensions it is spongy in appearance, because it has many large air spaces between the cells. Palisade mesophyll cells are near the upper surface of the leaf where they receive more sunlight. They therefore contain more chloroplasts than spongy mesophyll cells (**Figure 3.3**).

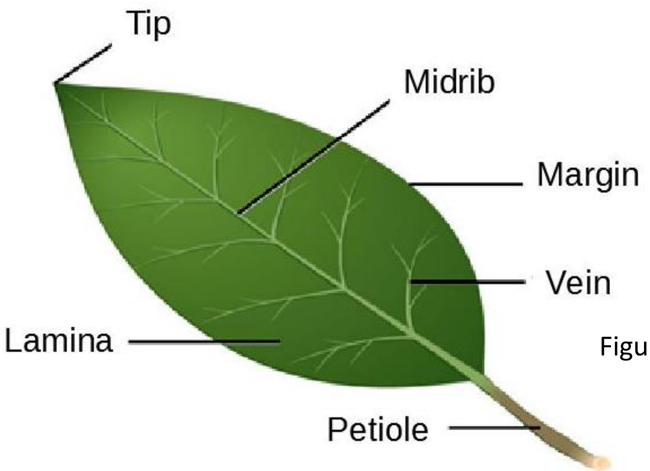


Figure 3.2. The external structure of the leaf.

A). **External Structure of a Leaf**

*Explain each external part of a leaf

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

B). Internal structure of a leaf

On the other hands, the internal structure of a leaf is complex and serves various functions crucial for the plant's survival. Here is a detailed look at the internal structure and function of leaf parts (**Figure 3.3**):

(1). Epidermis

The epidermis is the outermost layer of cells covering the leaf. It consists of the upper and lower epidermis, which protect the leaf and are involved in gas exchange. The epidermis houses stomata, which are openings controlled by guard cells. These stomata are crucial for allowing gas exchange between the leaf and the environment.

(2). Mesophyll

Beneath the epidermis lies the mesophyll, which is divided into two layers:

(**A**). **Palisade Mesophyll**: This layer is made up of column-shaped, tightly-packed cells and is primarily responsible for photosynthesis due to its high chloroplast content.

(**B**). **Spongy Mesophyll**: Below the palisade layer, this layer consists of loosely arranged cells with large intercellular spaces. It facilitates gas exchange and contains chloroplasts for photosynthesis.

(**3**). **Vascular Bundles (Veins)**

The vascular bundles include xylem and phloem. Xylem transports water and minerals from the roots to the leaves, while phloem distributes the sugars produced by photosynthesis throughout the plant.

Other structures of a leaf:

Cuticle

A waxy layer known as the cuticle covers the epidermis, significantly reducing water loss from the leaf surface.

Trichomes

Some leaves may have trichomes, which are small hairs that can help deter herbivory, reduce transpiration, and sometimes store toxic compounds1.

These components work together to ensure the leaf can perform its primary function—**photosynthesis**—efficiently, converting light energy into chemical energy stored in glucose, while also managing water retention and gas exchange.

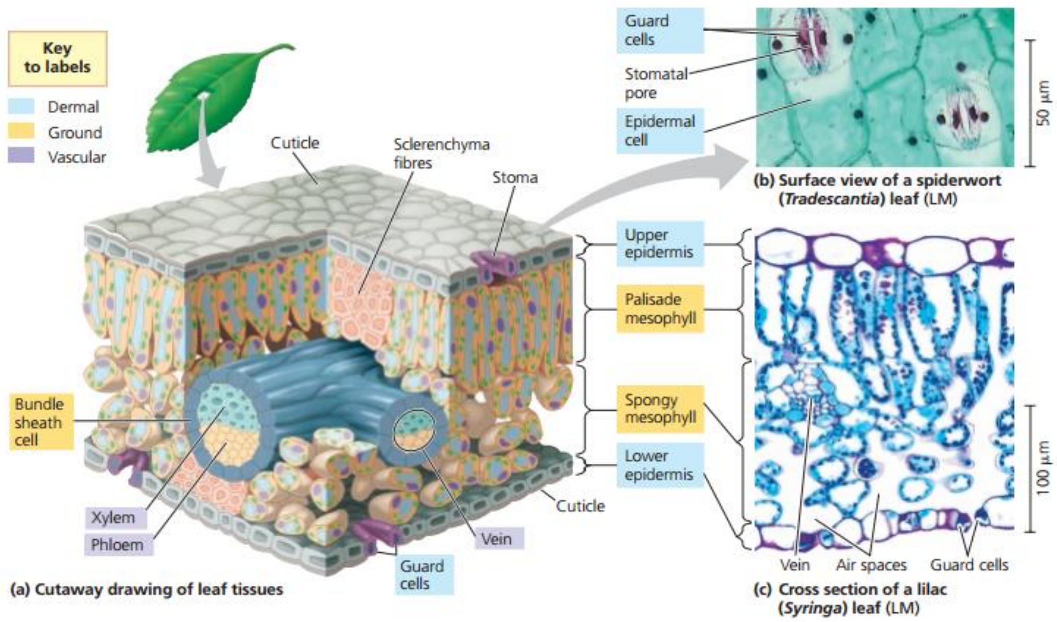


Figure 3.3. Internal structure of leaf

Self-test **Write true if the statement is correct or false if not.**

1. The cuticle is a waxy layer that covers the leaf surface and reduces water loss.
2. The stomata are openings in the leaf epidermis that regulate gas exchange.
3. The palisade parenchyma is a layer of loosely arranged cells in the mesophyll that allows air space for gas exchange.
4. The stipules are structures that are located at the base of the petiole and may resemble scales, spines, glands, or leaf-like structures.

2.2.2. The site of photosynthesis

Where does photosynthesis take place?

Dear learner, chloroplasts are essential organelles found in plant cells and algae, playing a critical role in photosynthesis. Please refer to **Figure 3.4** for an overview of their structure**:**

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

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

🛠 **Self-test**

1) Can you explain the structure and location of chloroplasts in plant cells? In addition, what is their role in photosynthesis?
2) Diagram the internal structure of a chloroplast and explain how its components interact and facilitate the process of photosynthesis.
3) Describe what happens to an electron in a biological molecule such as chlorophyll when a photon of light energy is absorbed.
4) Describe the relationships among the chloroplast, stroma, grana, thylakoids, and photosystems.
5) How does the reaction center chlorophyll interact with the antenna pigments in a photosystem?

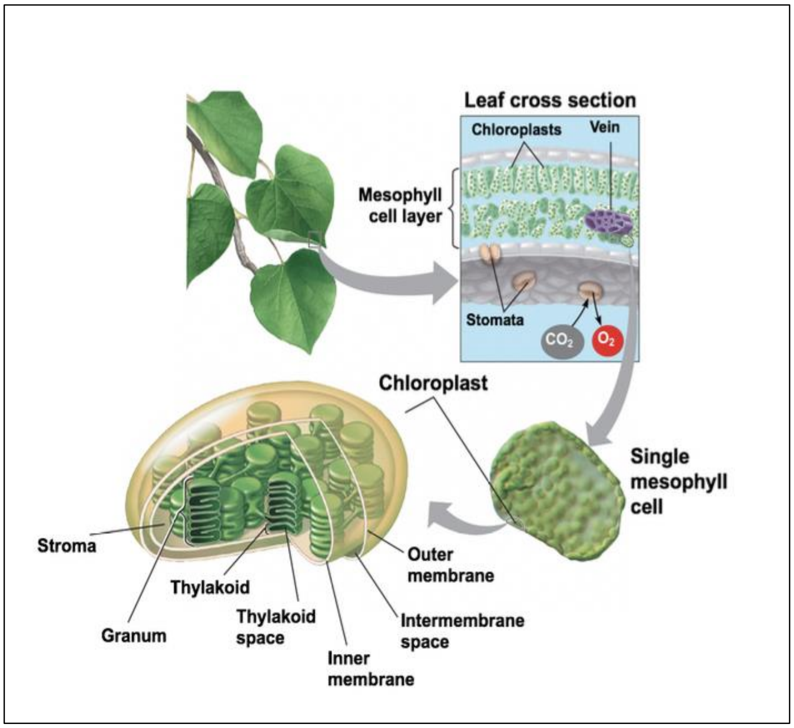


Figure 3.4. The structure of a chloroplast and its location within a plant cell and leaf

Self-test **Choose the appropriate answer**

1. Which organelle is the site of photosynthesis in plants and algae? A) Mitochondria B) Chloroplast C) Nucleus D) Ribosome

2. Which layer of leaf tissue contains most of the photosynthetic cells? A) Epidermis B) Cuticle C) Mesophyll D) Vascular bundle

3.2.3. Photosynthetic pigments

What is a photosynthetic pigment?

Dear learner, photosynthetic cells contain special pigments that absorb light energy. Different pigments respond to different wavelengths of visible light. **Pigments** are chemical compounds, which reflect only certain wavelengths of visible light. This makes them appear "colorful". Flowers, corals, and even animal skin contain pigments, which give them their particular colors. More important than their reflection of light is the ability of pigments to **absorb** certain wavelengths. Because they interact with light to absorb only certain wavelengths, pigments are useful to plants and other **autotrophs.** In plants, algae, and cyanobacteria, pigments are the means by which the energy of sunlight is captured for photosynthesis. However, since each pigment reacts with only a narrow range of the spectrum, there is usually a need to produce several kinds of

Self-test

1. What color of light is least effective in driving photosynthesis? Explain.
2. Describe the physical properties of light and explain the relationship between a wavelength of light and its energy?

pigments, each of a different color, to capture more solar energy. There are three basic classes of pigments.

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

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

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

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

Self-Test

Write true if the statement is correct and false if the statement is incorrect.

1. Photosynthetic pigments are molecules that absorb light energy and transfer it to the reaction centers of photosynthesis.

2. Chlorophyll is the only type of photosynthetic pigment.
3. Photosynthetic pigments are located in the cytoplasm of the cell.
4. Photosynthetic pigments reflect the color of light that they absorb.
5. Photosynthetic pigments can vary depending on the environmental conditions and the type of organism.

Activity 3. 4

- What is the significance that the combined absorption spectra of chlorophylls a and b roughly match the action spectrum of photosynthesis? Would photosynthesis be more efficient if their individual absorption spectra coincided exactly?

Absorption spectra of photosynthetic pigments

The absorption spectrum is a term that describes what and what is its function?

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

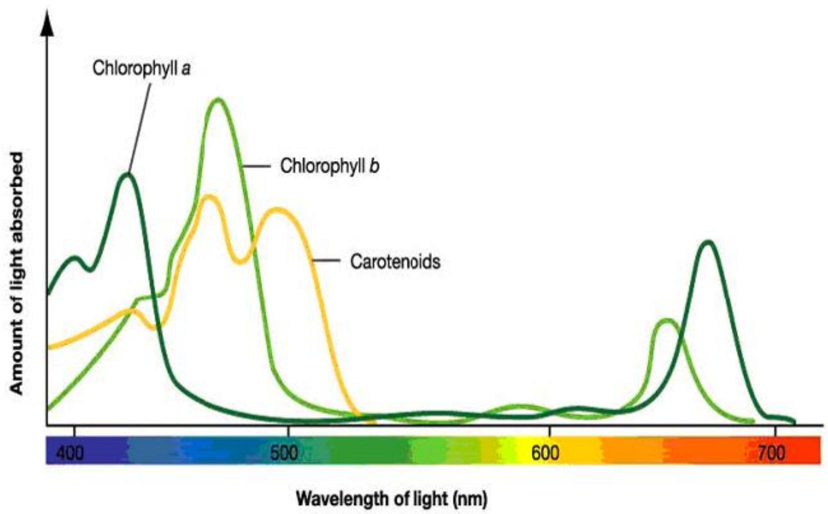


Figure 3.5. Absorption spectrum of *Chlorophyll a*, *Chlorophyll b*, and carotenoids

Practical activity - paper chromatography

Self-test

Match the following sentence with the appropriate terms

S.no	**A)** Absorption spectrum **B)** Chlorophyll **C)** Mesophyll **D)** Red edge **E)** Carotenoid	
1	A pigment that absorbs blue-violet light and reflects yellow-orange light	
2	A graph that shows the absorbance of different wavelengths of light by a pigment	
3	A light-absorbing pigment that reflects green light and is found in chloroplasts	
4	A region of rapid change in reflectance around 700 nm due to chlorophyll absorption	
5	A layer of leaf tissue that contains most of the photosynthetic cells	

3.2.4. Light-dependent and light-independent reactions

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

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

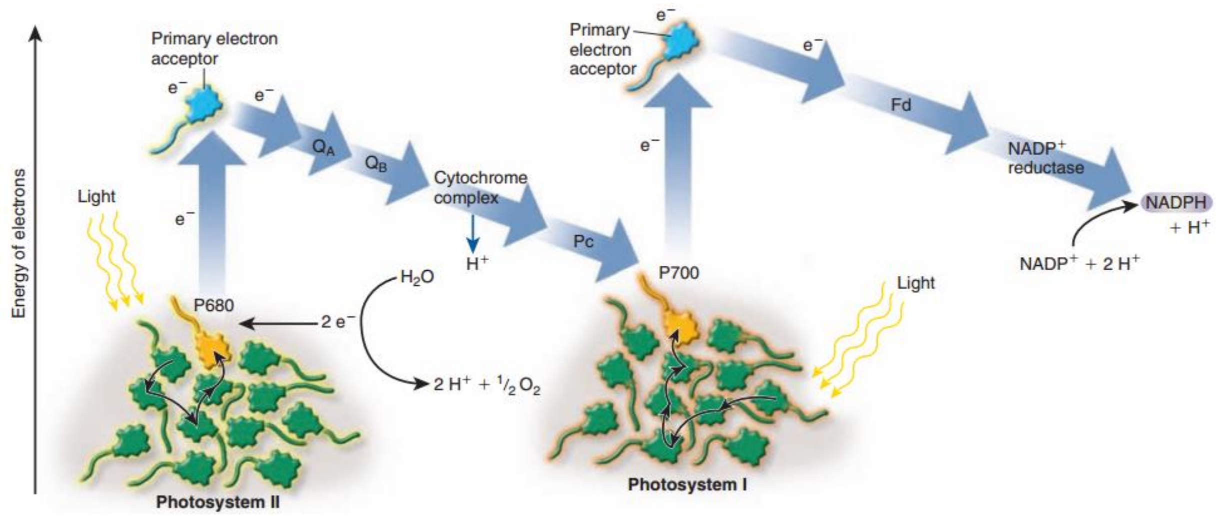
?	What is the difference between cyclic and non-cyclic phosphorylation?

Dear learner, the light reactions are the steps of photosynthesis that convert solar energy to chemical energy. Water is split, providing a source of electrons and protons (hydrogen ions, H+) and giving off O_2 as a by-product (Figure 3.6). Light absorbed by chlorophyll drives a transfer of the electrons and hydrogen ions from water to an acceptor called $NADP^+$ (nicotinamide adenine dinucleotide phosphate), where they are temporarily stored. (The electron acceptor NADP + is first cousin to NAD^+, which functions as an electron carrier in cellular respiration; the two molecules differ only by the presence of an extra phosphate group in the NADP + molecule.) The light reactions use solar energy to reduce NADP + to NADPH by adding a pair of electrons along with an H^+. The light reactions also generate ATP, using chemiosmosis to power the addition of a phosphate group to ADP, a process called photophosphorylation.

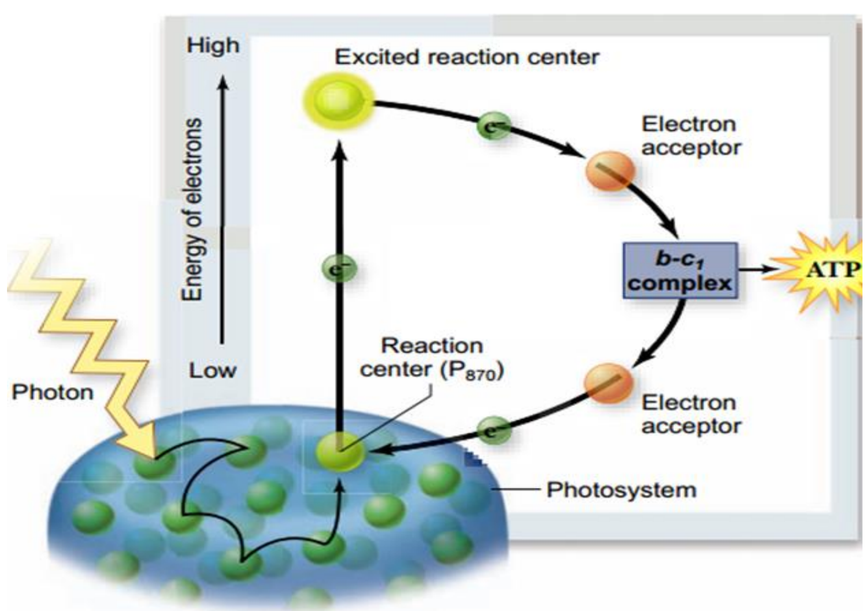
🛠 **Self-test**

1) Distinguish between the light-dependent reactions and carbon fixation reactions of photosynthesis.
2) *In what ways do the carbon fixation reactions depend on the light-dependent reactions?*

Thus, light energy is initially converted to chemical energy in the form of two compounds: NADPH and ATP. NADPH, a source of electrons, acts as “reducing power” that can be passed along to an electron acceptor, reducing it, while ATP is the versatile energy currency of cells. Notice that the light reactions do not produce sugar.



a). Non-cyclic photophosphorylation



b). cyclic photophosphorylation

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

Dear learners, please refer to Table 3.1 below to differentiate between cyclic and non-cyclic photophosphorylation**.**

Table 3.1. Comparison of cyclic and non-cyclic photophosphorylation

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

Photosystem I and photosystem II

What is the difference between photosystem I & Photosystem II?

Dear learner, please read carefully and try to differentiate between the differences and similarities of Photosystem I and Photosystem II described below.

1. Electrons (e^-) in chlorophyll molecules in photosystem II are excited by the energy in photons of light: they become more energetic. Because of the extra energy, they escape from the chlorophyll and pass to an electron acceptor (the primary electron acceptor).

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

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

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

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

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

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

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

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

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

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

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

Light-Independent Reactions (Calvin cycle)

What is a light dependent reaction?

Dear learner, this is the second step in the mechanism of photosynthesis. The chemical processes of photosynthesis occurring independent of light are called dark reactions. It takes place in the stroma of the chloroplast. The dark reaction is purely enzymatic and it is slower than the light reaction. Dark reaction does not require light. In a dark reaction, the sugars are synthesized from CO_2.

The energy-poor CO_2 is fixed to energy-rich carbohydrates using the energy-rich compound, ATP, and the assimilatory power, $NADPH_2$ of light reaction. The process is called carbon fixation or carbon assimilation.

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

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

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

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

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

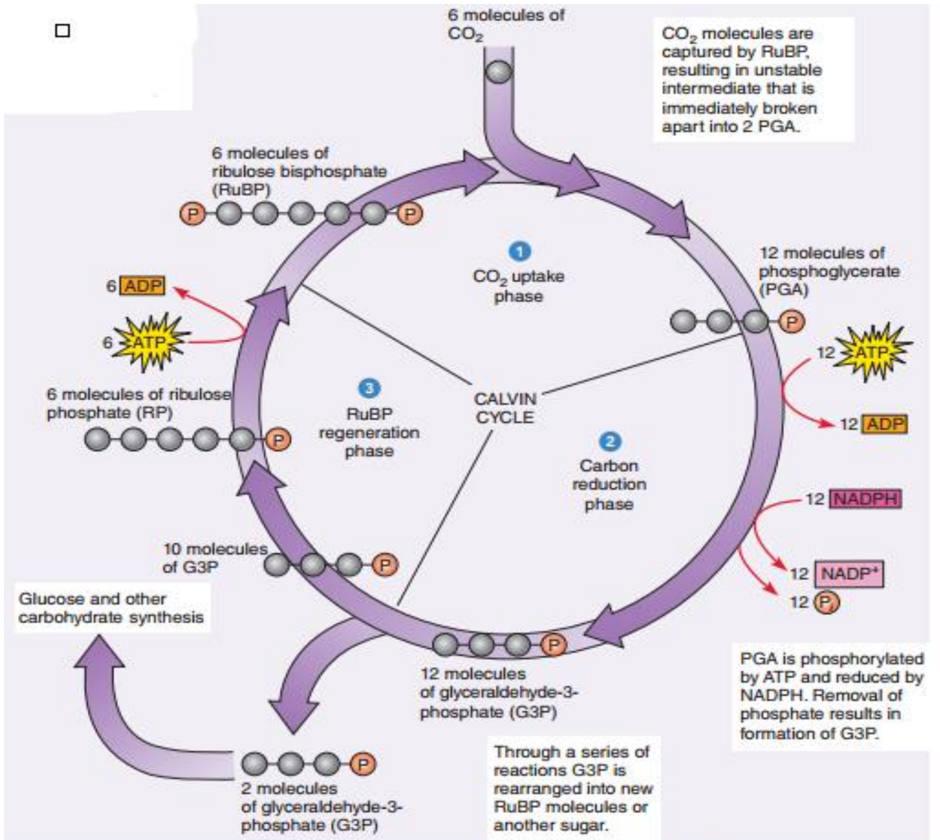


Figure 3.7. Calvincycl (C3 cycle)

In the dark reaction, CO_2 is fixed to carbohydrates and the CO_2 acceptor ribulose-diphosphate is regenerated. In the Calvin cycle, 12NADPH$_2$ and 18 ATPs are required to fix 6CO_2 molecules into one hexose sugar molecule (fructose- 6-phosphate).

C_4 plants

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

The basic C4 cycle consists of four stages:

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

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

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

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

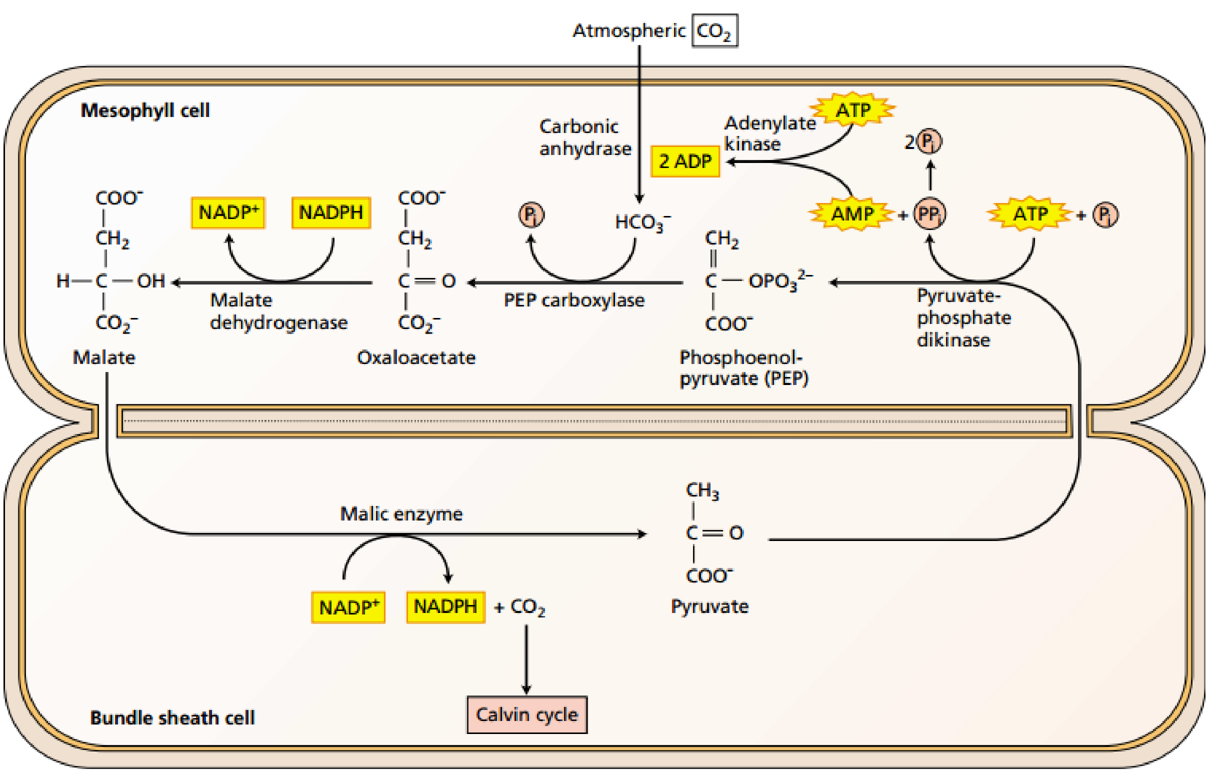


Figure 3.8. The C_4 photosynthetic pathway

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

At night, CO_2 is captured by PEP carboxylase in the cytosol, and the malate that forms from the oxaloacetate product is stored in the vacuole. During the daytime, the stored malate is transported to the chloroplast and decarboxylated by NADP-malic enzyme, the released CO_2 is fixed by the Calvin cycle, and the NADPH is used for converting the decarboxylated triose phosphate product to starch.

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

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

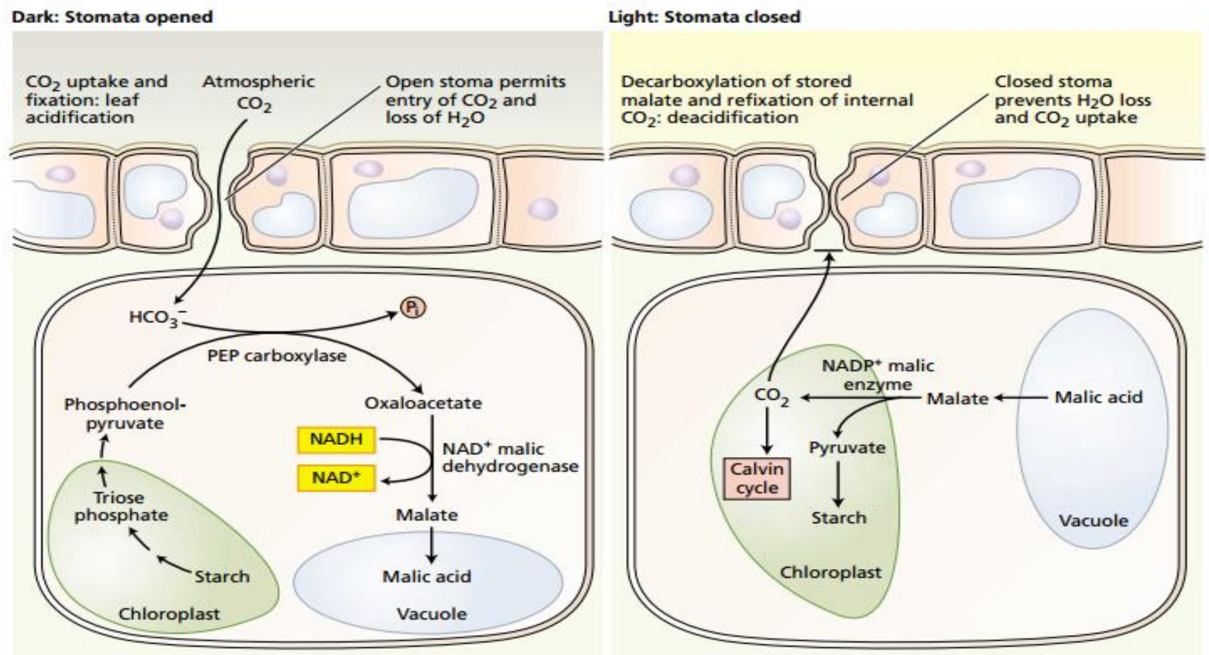


Figure 3.9. CAM cycle

Photorespiration

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

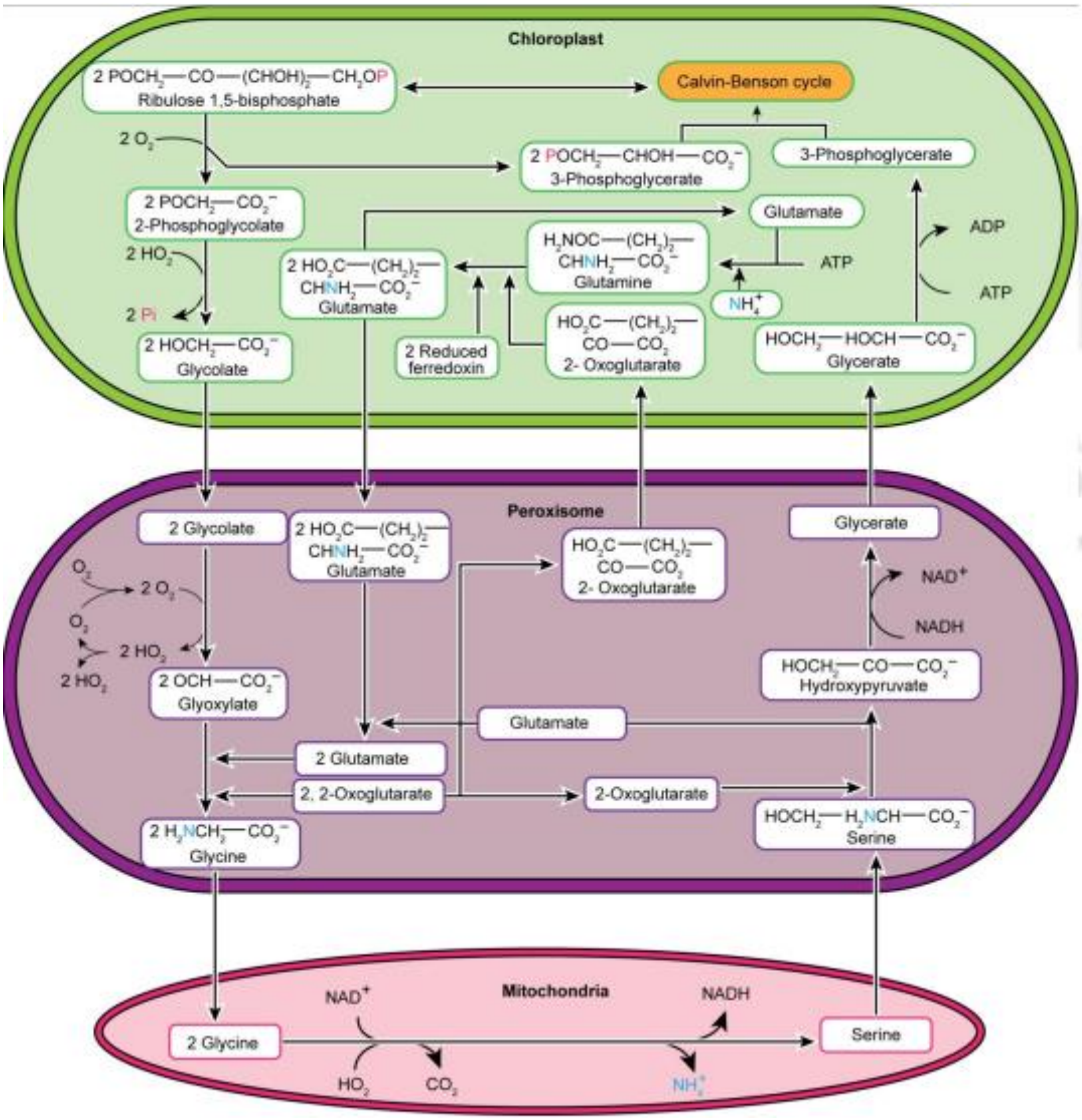


Figure 3.10 The photorespiratory cycle.

🛠 Self-Test

Choose the correct answer from the given alternatives.

1. What is the main product of the light-dependent reactions?

   a) Glucose
   b) Oxygen
   c) NADPH
   d) ATP

2. What is the main product of the light-independent reactions?

   a) Glucose
   b) Oxygen
   c) NADPH
   d) ATP

3. Where do the light-dependent reactions take place in a plant cell?

   a) Cytoplasm
   b) Chloroplast
   c) Mitochondria
   d) Nucleus

4. Where do the light-independent reactions take place in a plant cell?
   a) Cytoplasm
   b) Chloroplast
   c) Mitochondria
   d) Nucleus

5. What is the name of the cycle that describes the light-independent reactions?
   a) Krebs cycle
   b) Calvin cycle
   c) Citric acid cycle
   d) Glycolysis cycle

🛠 Self- test

- Distinguish between how rubisco acts to make RuBP and how it oxidizes RuBP.
- Compare the function of carbon fixation in the C3, C4, and CAM pathways.
- How do C4 plants and CAM plants differ?

3.2.5. Contributions of Photosynthesis for the Continuity of Life, for O_2 And Co_2 Balance and Global Warming

INTRODUCTION

Dear learner, what is the Contributions of photosynthesis for the continuity of life, for O_2 and CO_2 balance and global warming.

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

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

🛠 **Self-Test** **(**Write True if the statement is correct and False if the statement id incorrect**)**

1. Photosynthesis is the only process that produces oxygen on Earth.
2. Photosynthesis reduces the amount of carbon dioxide in the atmosphere.
3. Photosynthesis increases the greenhouse effect and global warming.
4. Photosynthesis is essential for the continuity of life on Earth.
5. Photosynthesis occurs only in plants.

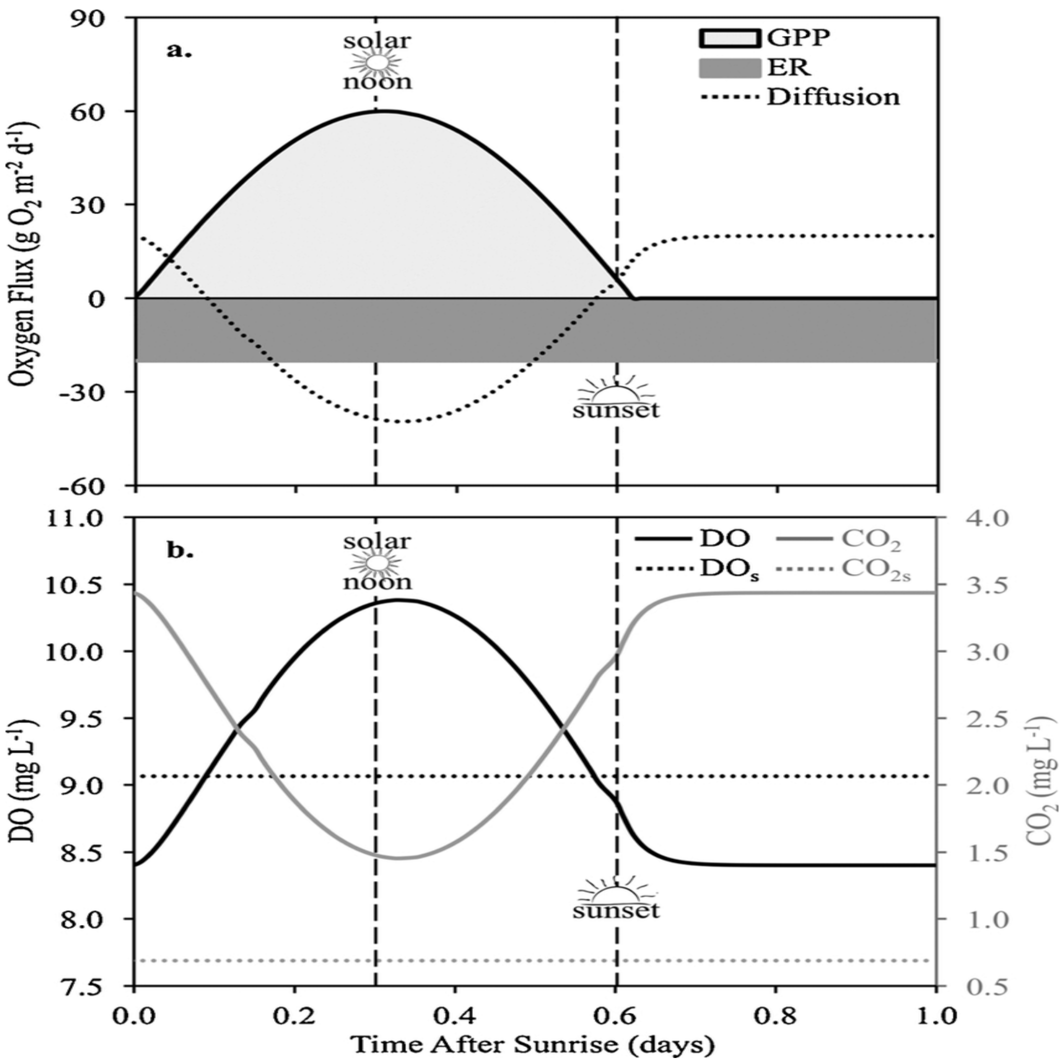


Figure 3.11. Carbondioxide –oxygen balance in the atomospher (Idealized daily rates of photosynthesis (GPP), respiration (ER), and diffusion (a.) with resultant dissolved O 2 concentration and saturated (DO s) concentration at 20 °C (b.)).

REVIEW QUESTIONS

I. Choose the correct answer for the following questions.

1. The light-dependent reactions of photosynthesis are responsible for the production of

a. glucose. b. CO_2. c. ATP and NADPH. d. H_2O.

2. Which region of a chloroplast is associated with the capture of light energy?

a. Thylakoid membrane b. Outer membrane c. Stroma d. Both a and c are correct.

3. The colors of light that are most effective for photosynthesis are

a. red, blue, and violet.

b. green, yellow, and orange.

c. infrared and ultraviolet.

d. All colors of light are equally effective.

4. During noncyclic photosynthesis, photosystem I functions to ___________, and photosystem II functions to ______________.

a. synthesize ATP; produce O_2

b. reduce $NADP^+$; oxidize H_2O

c. reduce CO_2; oxidize NADPH

d. restore an electron to its reaction center; gain an electron from water

5. How is a reaction center pigment in a photosystem different from a pigment in the antenna complex?

a. The reaction center pigment is a chlorophyll molecule.

b. The antenna complex pigment can only reflect light.

c. The reaction center pigment loses an electron when it absorbs light energy.

d. The antenna complex pigments are not attached to proteins.

6. The ATP and NADPH from the light reactions are used

a. in glycolysis in roots.

b. directly in most biochemical reactions in the cell.

c. during the reactions of the Calvin cycle to produce glucose.

d. to synthesize chlorophyll.

7. The carbon fixation reaction converts

a. inorganic carbon into an organic acid.

b. CO_2 into glucose.

c. inactive rubisco into active rubisco.

d. an organic acid into CO_2.

8. C4 plants initially fix carbon by

a. the same pathway as C3 plants, but they modify this product.

b. incorporating CO_2 into oxaloacetate, which is converted to malate.

c. incorporating CO_2 into citrate via the Krebs cycle.

d. incorporating CO_2 into glucose via reverse glycolysis.

9. The overall flow of electrons in the light reactions is from

a. antenna pigments to the reaction center.

b. H_2O to CO_2.

c. photosystem I to photosystem II.

d. H_2O to NADPH.

10. If you could measure pH within a chloroplast, where would it be lowest?

a. In the stroma

b. In the lumen of the thylakoid

c. In the cytoplasm immediately outside the chloroplast

d. In the antenna complex

11. The excited electron from photosystem I

a. can be returned to the reaction center to generate ATP by

cyclic photophosphorylation.

b. is replaced by oxidizing H_2O.

c. is replaced by an electron from photosystem II.

d. Both a and c are correct.

12. If the Calvin cycle runs through six turns

a. all of the fixed carbon will end up in the same glucose molecule.

b. 12 carbons will be fixed by the process.

c. enough carbon will be fixed to make one glucose, but they will not all be in the same molecule.

d. one glucose will be converted into six CO_2.

13. Which of the following are similarities between the structure and function of mitochondria and chloroplasts?

a. They both create internal proton gradients by electron transport.

b. They both generate CO_2 by oxidation reactions.

c. They both have a double membrane system.

d. Both a and c are correct.

14. Given that the C4 pathway gets around the problems of photorespiration, why don't all plants use it?

a. It is a more recent process, and many plants have not had time to evolve this pathway.

b. It requires extra enzymes that many plants lack.

c. It requires special transport tissues that many plants lack.

d. It also has an energetic cost.

15. If the thylakoid membrane became leaky to ions, what would you predict to be the result on the light reactions?

a. It would stop ATP production.

b. It would stop NADPH production.

c. It would stop the oxidation of H_2O.

d. All of the choices are correct.

16. The overall process of photosynthesis

a. results in the reduction of CO_2 and the oxidation of H_2O.

b. results in the reduction of H_2O and the oxidation of CO_2.

c. consumes O_2 and produces CO_2.

d. produces O_2 from CO_2.

✓ **Self-evaluation check list**

Put a tick (√) against each of the following tasks, which you can perform. If you cannot perform any of these tasks, go back and read the lesson for that particular task.

I Can:

S.no	**Questions**	✓ **Check**
1	• Define photosynthesis.	
2	• Explain the process of dark and light reaction of photosynthesis.	
3	• Describe the external and internal structure of a leaf.	
4	• Describe the different chlorophyll pigments involved in the absorption of light energy.	
5	• Analyze an absorption spectra of the chlorophyll pigments from the graph.	
6	• Describe cyclic and non-cyclic photophosphorylation.	
7	• Show an absorption spectra of chlorophyll a and chlorophyll b using graph.	
8	• Explain the process of Calvin cycle.	

9	• Compare cyclic and non-cyclic photophosphorylation.	
10	• Differentiate between C3 , C4 plants, and CAM Plants.	
11	• Justify the reason why the rate of photorespiration is less in C4 plants as compared to C3 plants.	
12	• Summarize the process of photosynthesis using chemical equation.	
13	• Conduct an experiment to show the release of energy during photosynthesis.	
14	• Conduct an experiment to show the presence of starch in green leaves.	
15	• Explain the significances of photosynthesis.	

SECTION 3.3. CELLULAR RESPIRATION

INTRODUCTION

Dear learner, I hope you have a good understanding of the topics you have learned above. Under this topic you will learn in detail about cellular respiration.

MINIMUM LEARNING COMPETENCIES

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

- define cellular respiration
- Describe the process of glycolysis.

- List the products formed at the end of glycolysis.
- Describe the structure of mitochondria.
- Explain how energy is harvested in aerobic respiration.
- Describe the different stages of aerobic respiration.
- Compare and contrast aerobic and anaerobic respiration.
- Write the chemical equation of aerobic respiration.
- State the products of alcoholic fermentation by yeast.
- Show the mechanism electron transport system in mitochondria.
- explain the difference between substrate-level phosphorylation and oxidative phosphorylation
- Explain how proton gradients are generated across membranes.
- Explain the significances of fermentation by microorganisms.
- Justify why an athlete is using anaerobic respiration /lactate fermentation during a race.

Cellular respiration

What is cellular respiration?

Dear learner, Cellular respiration is the process by which cells produce energy from glucose in the form of energy storing compound called **ATP (AdenosineTri-Phosphate)** for various cellular activities. The energy released by cellular respiration is temporarily captured by the formation of Adenosine Triphosphate (ATP) within the cell. It is often referred to as the energy currency of the cell, and this can be compared to depositing cash in a bank.

ATP can be used to store energy for future reactions or be withdrawn to pay for reactions when energy is required by the cell. Animals store the energy obtained from the breakdown of food as ATP. Likewise, plants capture and store the energy they derive from light during photosynthesis in ATP molecules. ATP is a nucleotide consisting of an adenine base attached to a ribose sugar, which is attached to three phosphate groups (**see Figure 3.12**). These three phosphate groups are linked to one another by two high-energy bonds called phosphoanhydride bonds. When one phosphate group is removed by breaking a phosphoanhydride bond in a process called hydrolysis, energy is released, and ATP is converted to **adenosine diphosphate** (**ADP**). Similarly, energy is also released when a phosphate is removed from **ADP** to form adenosine monophosphate (AMP). This free energy can be transferred to other molecules to make unfavorable reactions in a cell favorable.

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

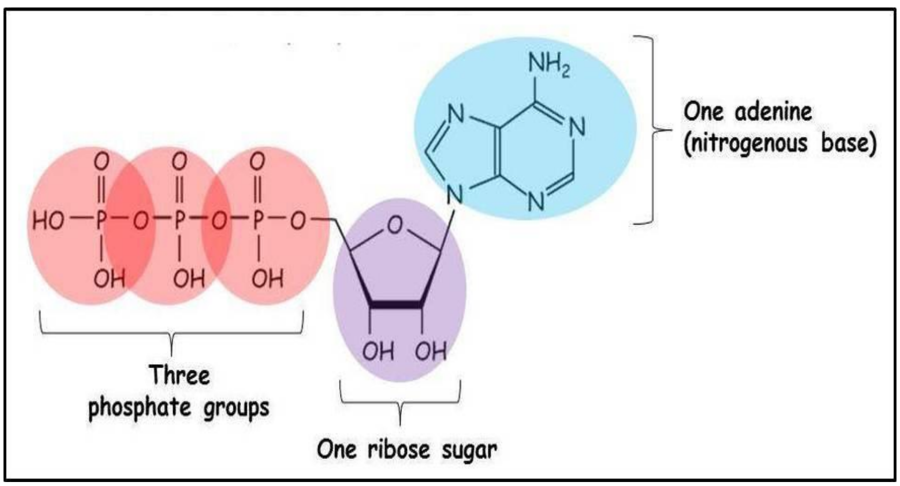


Figure 3.12. Adenosine triphosphate

Coupled Reactions

How are coupled reactions important to cell function? How is ATP involved in coupled reactions.

Dear learner, many biochemical reactions in which energy is given off- (is called **exothermic**), whereas many others reactions that require energy (are called **endothermic**). In order for both processes to be carried out efficiently, they must be "coupled". Usually, a **coupled reaction** will involve ATP or some similar molecules. A coupled reaction is carried out when two reactions occur nearly simultaneously. The first reaction must be **exothermic** and that **gives off energy.** The second reaction is endothermic, which immediately **uses the energy produced** from the first reaction.

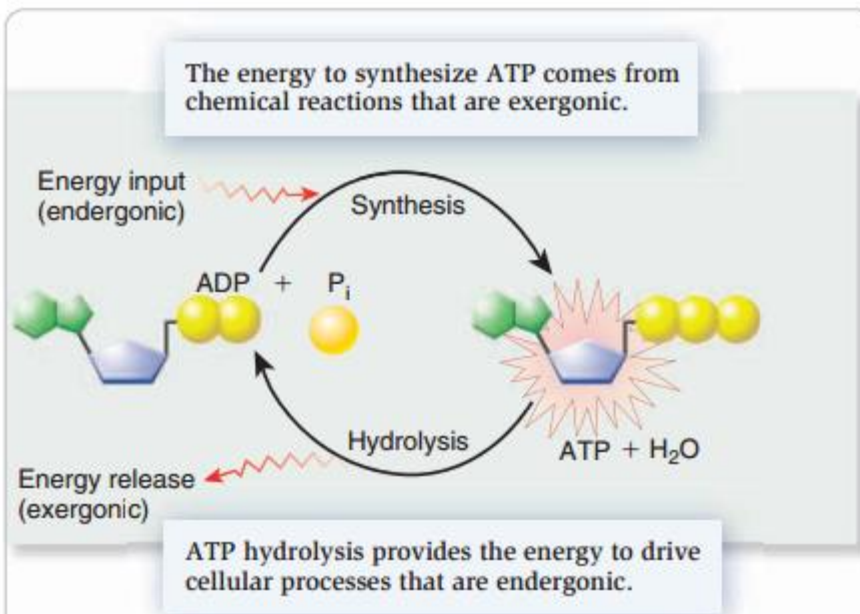


Figure 3.13. ATP cycle

Dear learner, an example of a coupled reaction is the hydrolysis of ATP and the contraction of muscle tissue (see **Figure 3.13**). Two proteins, actin and myosin, form a loose complex called **actomyosin**. When ATP is added to isolated actomyosin, the protein fibers contract. The **hydrolysis of ATP releases energy**, which is used by muscles to contract. The coupled reaction is:

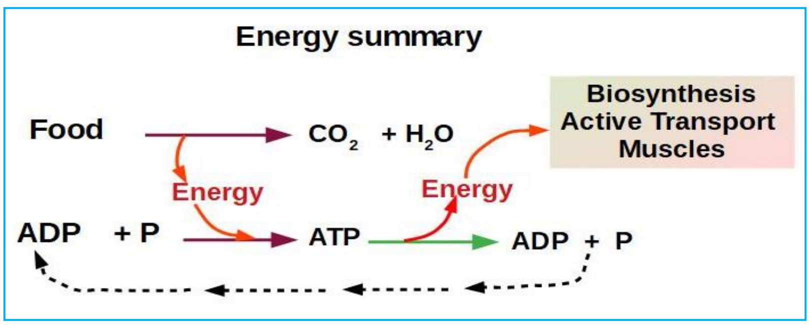
A. ATP + H_2O →→ ADP + P + energy

B. Relaxed muscle + energy →→ contracted muscle

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

A. Creatine --- PO_3 + H_2O →→ creatine H + HPO_4^{-3} + energy
B. ADP + HPO_4^{-3} + energy →→ ATP + H_2O

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



🛠 Self-Test (choose the appropriate answer)

1. What is the name of the process that converts glucose into two molecules of pyruvate, producing a net gain of two ATP and two NADH?

   a) Glycolysis b). Krebs cycle c). Electron transport chain d). Fermentation

2. What is the name of the molecule that acts as the main energy currency of the cell, storing and releasing energy in its phosphate bonds?

   a) ADP b). ATP c). AMP d). NAD+

3. What is the name of the process that transfers electrons from NADH and FADH2 to a series of protein complexes, generating a proton gradient across the inner mitochondrial membrane?

a) Glycolysis b). Krebs cycle c). Electron transport chain d). Fermentation

4. What is the name of the enzyme that uses the proton gradient to synthesize ATP from ADP and Pi, coupling the exergonic electron transport with the endergonic ATP synthesis?

   a) ATP synthase b). ATPase c). ATP hydrolase d). ATP transferase

5. What is the name of the process that occurs in the absence of oxygen, regenerating NAD+ from NADH by reducing pyruvate to either lactate or ethanol and carbon dioxide?

   a) Glycolysis b). Krebs cycle c). Electron transport chain d). Fermentation

3.3.1. The site of cellular respiration

🛠 Self-test

- What is the starting material for cellular respiration?
- How is the energy from nutrient molecules temporarily stored?
- Where in the cell does cellular respiration begin?

🛠 Self-test

- What is the role of oxygen in cellular respiration?

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

Stages of respiration

Dear learner, cellular respiration involves many chemical reactions. The reactions can be summed up in this equation

$$\underset{\text{glucose}}{C_6H_{12}O_6} + 6O_2 \longrightarrow 6CO_2 + 6H_2O + ATP$$

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

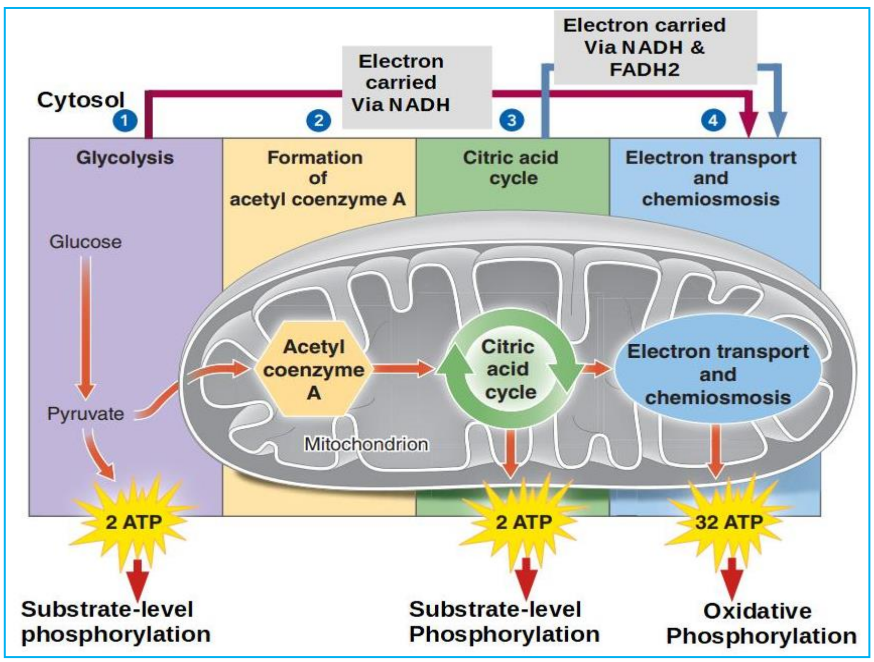


Figure 3.14. Stages of cellular respiration

<u>Stage I: Glycolysis</u>

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

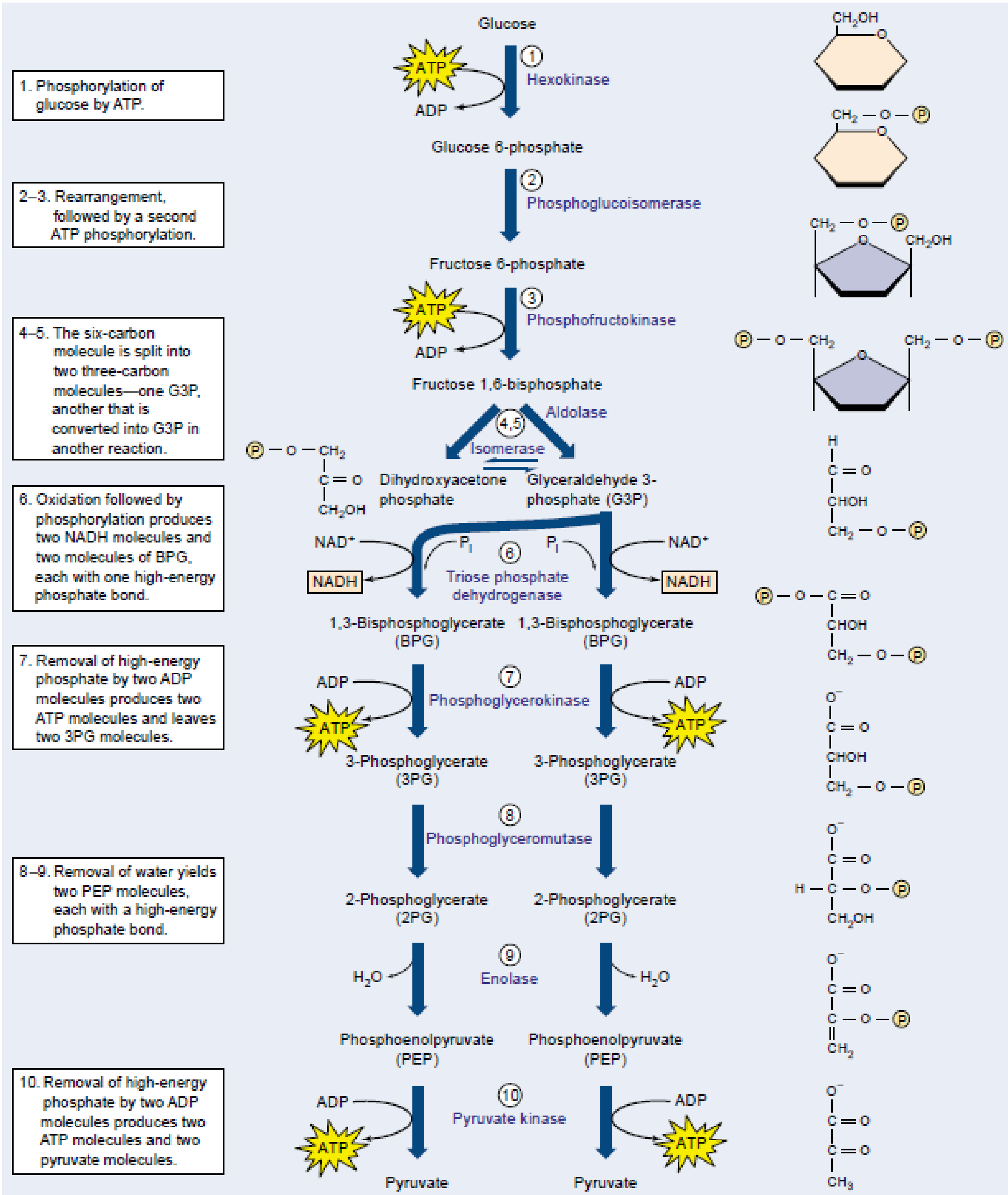


Figure 3.15. Glycolysis pathway.

Activity: 3.5.

What is the overall equation that describe cellular respiration? What is substrate level phosphorylation, and in what stages of cellular respiration does it generate ATP? What is oxidative phosphorylation, and in what stages of cellular respiration does it generate ATP?

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

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

• The cleavage phase (steps 4–5) breaks this six-carbon molecule into two molecules of glyceraldehyde-3-phosphate.
• The energy liberation phase (steps 6–10) produces four ATP, two NADH, and two molecules of pyruvate. Because two molecules of ATP are used in the energy investment phase, the net yield is two molecules of ATP.

Net reaction of glycolysis

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

Stage II: Pyruvate oxidation (link reaction)

Dear learner, in order to oxidize to pyruvate, which is the product of glycolysis and enter the next pathway, it must undergo several changes to become acetyl Coenzyme A (acetyl CoA). Acetyl CoA is a molecule that is further converted to oxaloacetate, which enters the citric acid cycle (Krebs cycle). The conversion of pyruvate to acetyl CoA is a **three-step process** (**Figure 3.16**).

Step 1. A carboxyl group is removed from pyruvate, releasing a molecule of carbon dioxide into the surrounding medium. (Note: carbon dioxide is one carbon attached to two oxygen atoms and is one of the major end products of cellular respiration).

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

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

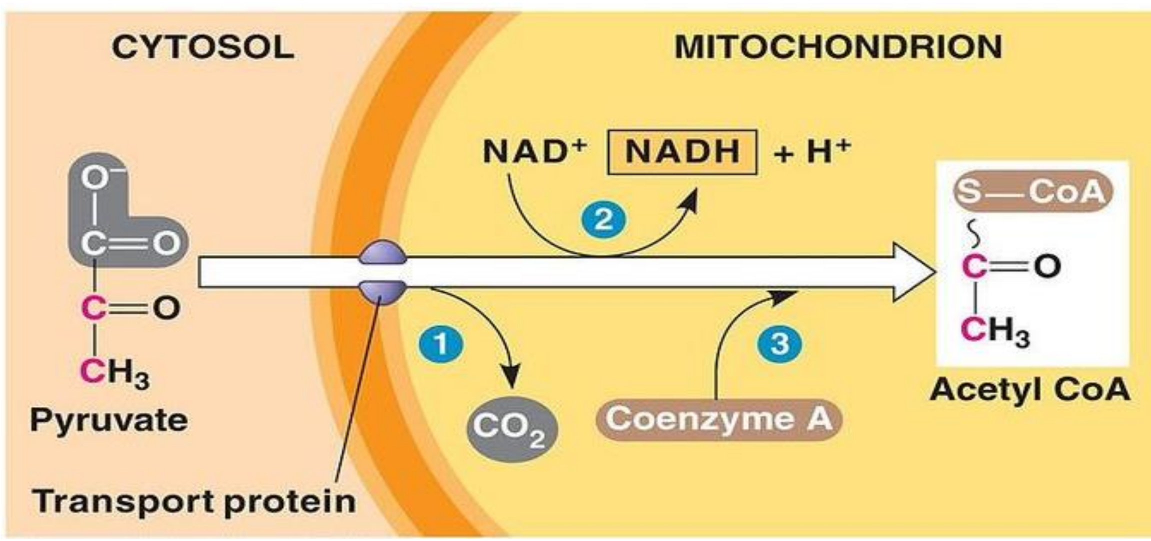


Figure 3.16. Pyruvate oxidation (link reaction)

The overall reaction:

2pyruvate + 2NAD+ + 2 CoA --> 2 acetyl-CoA + 2NADH + $2H^+$ + $2CO_2$.

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

Net reaction:

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

Self-Test

Choose the appropriate answer

1. What is the net gain of ATP molecules per glucose molecule in glycolysis?

   a) 2   b). 4   c). 6   d). 8

2. Which enzyme catalyzes the rate-limiting step of glycolysis, the phosphorylation of fructose-6-phosphate to fructose-1,6-bisphosphate?

   a) Hexokinase   b). Phosphofructokinase   c). Pyruvate kinase   d). Aldolase

3. Which molecule acts as the electron acceptor in glycolysis, forming a reduced coenzyme that can be used in other metabolic pathways?

   a) NAD+   b). FAD   c). NADP+   d). Coenzyme A

4. What is the fate of pyruvate, the end product of glycolysis, under anaerobic conditions (such as in muscle cells during intense exercise)?
   a) It is converted to acetyl-CoA and enters the citric acid cycle.
   b) It is converted to ethanol and carbon dioxide.
   c) It is converted to lactate and regenerates NAD+.
   d) It is converted to oxaloacetate and enters gluconeogenesis.

5. What is the name of the metabolic pathway that converts glucose to pyruvate in some bacteria and archaea, using a different set of enzymes than glycolysis?

   a) Pentose phosphate pathway
   b) Entner-Doudoroff pathway
   c) Calvin cycle
   d) Krebs cycle

Stage III: Kreb cycle

Dear learner, the Krebs cycle itself actually begins when acetyl-CoA combines with a four-carbon molecule called OAA (oxaloacetate) (Figure 3.17). This produces citric acid, which has six carbon atoms. This is why the Krebs cycle is also called the citric acid cycle. After citric acid forms, it goes through a series of reactions that release energy. The energy is captured in molecules of NADH, ATP, and $FADH_2$, another energy-carrying compound. Carbon dioxide is also released as product of these reactions. The final step of the Krebs cycle regenerates OAA, the molecule that began the Krebs cycle. This molecule is needed for the next turn through the cycle. Two turns are needed because glycolysis produces two pyruvate molecules when it splits glucose.

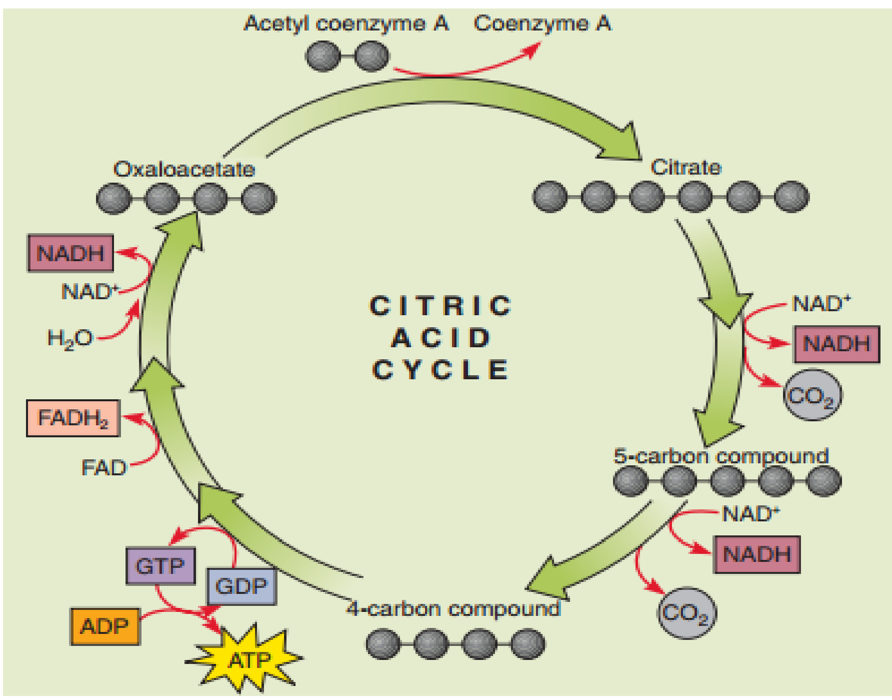


Figure 3.17 citric acid cycle (Krebs cycle)

Activity 3.6.

- What happens to the pyruvic acid generated in glycolysis before it enters the Krebs cycle?
- Where does the Krebs cycle occur?
- How does the Krebs cycle generate CO2, ATP, NADH, and FADH2?

Stage IV: Oxidative phosphorylation

What is oxidative phosphorylation?

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

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

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

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

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

1. **Site I** between FMN and Coenzyme Q at enzyme complex I.
2. **Site II** between cyt b and cyt C1 at enzyme complex III
3. **Site III** between cyt a and cyt a3 at enzyme complex IV

Dear learner, because energy generated by the transfer of electrons through the electron transport chain to O_2 is used in the production of ATP, the overall process is known as oxidative phosphorylation. This oxidation process refers to the coupling of the electron transport in respiratory chain with phosphorylation of ADP to form ATP. It is a process by which the energy of biological oxidation is ultimately converted to the chemical energy of ATP. Oxidative phosphorylation is responsible for 90% of the total ATP synthesis in the cell. Oxidative phosphorylation is the process in which ATP is formed as a result of the transfer of electrons from NADH or $FADH_2$ to O_2 by a series of electron carriers (**Figure 3.18**).

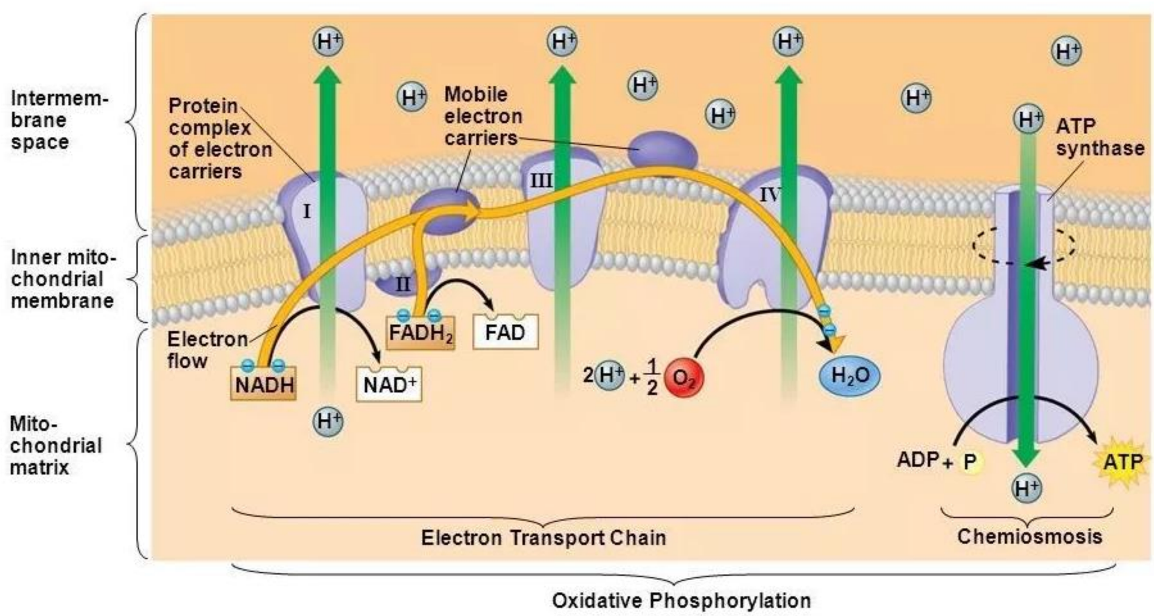
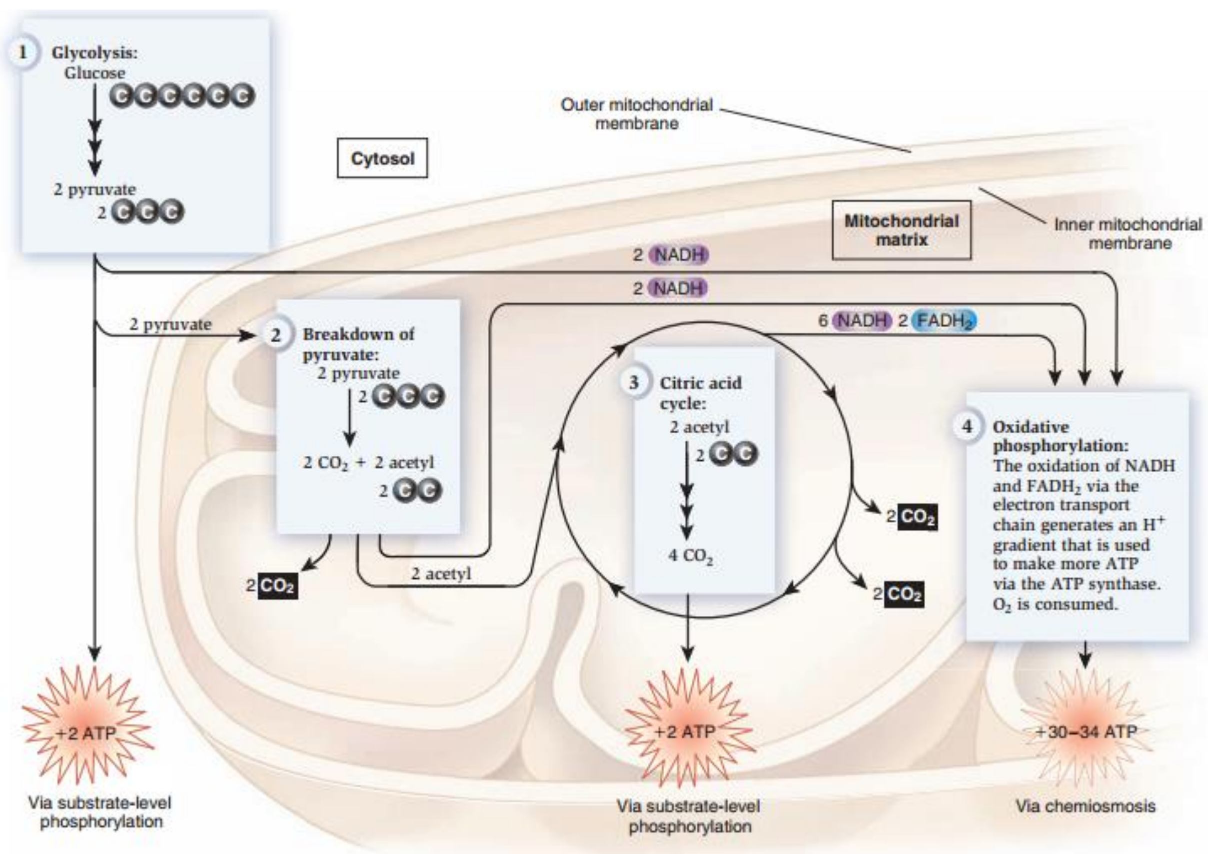


Figure 3.18. Electron transport and oxidative phosphorylation

Substrate-level phosphorylation means that phosphate is transferred to ADP from a high-energy phosphorylated organic compound. A couple of the enzymes in the glycolysis and citric acid cycle make ATP through substrate-level phosphorylation. However, only a small amount of ATP is made produced by this mechanism.

Oxidative phosphorylation synthesizes the bulk of a cell's ATP during cellular respiration. A protein motive force across a membrane provides the energy for ATP synthase to make ATP from ADP and inorganic phosphate. The proton-motive force is created by a large (1000-fold) difference in proton concentrations across a membrane. Mitochondria generate a proton gradient across the inner mitochondrial membrane for eukaryotic organisms. However, for prokaryotes, proton gradient (pH gradient) is maintained across their plasma membranes.



Mechanism

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

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

The energy budget of one glucose molecule

As from one glucose molecule, two pyruvate molecules are formed so that two cycles will be formed for the complete breakdown. Therefore, the total yield will be **6NADH, 2FADH2**, and **2 ATP** (**Figure 3.19**).

Self-Test

1) What happened to the electrons captured in NADH and FADH2 that the Krebs cycle generates?
2) How does the oxidation and reduction reaction constitute an electron transport system?
3) How does a proton (H+) gradient link the electrons from the Krebs cycle to ATP formation?
4) How efficiently does ATP capture the energy in the bond of a glucose molecule?
5) Calculate the theoretical estimate of 36ATPs generated per glucose
6) In what ways is 36 ATP an approximate?

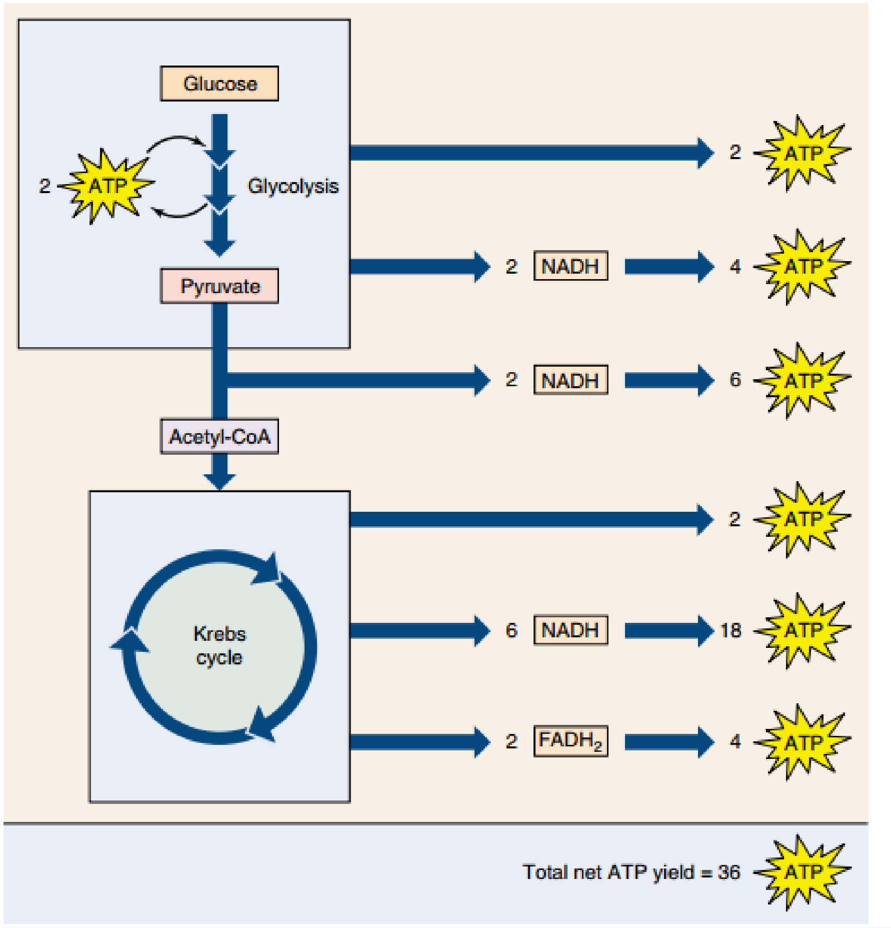


Figure 3. 19. Energy yield per glucose molecule breakdown.

The summary equation for aerobic respiration is:

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

☞

Coenzyme A coenzyme is derivedfrom a pantothenic acid needed for respiration

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

Dehydrogenation refers to the process of removinghydrogen from a molecule

Decarboxylation means removing carbon from a molecule

Terminal electron acceptor is the final molecule at the end

Energy from non-carbohydrate sources

How energy is produced from non-carbohydrate sources?

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

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

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

Catabolism can also harvest energy stored in fats obtained either from food or from storage cells in the body. After fats are digested to glycerol and fatty acids, the glycerol is converted to glyceraldehyde 3-phosphate, an intermediate of glycolysis. Most of the energy of a fat is stored in the fatty acids. A metabolic sequence called **beta oxidation** breaks the fatty acids down to two-carbon fragments, which enter the citric acid cycle as acetyl CoA. NADH and FADH2 are also generated during beta oxidation; they can enter the electron transport chain, leading to further ATP production. Fats make excellent fuels, in large part due to their chemical structure and the high energy level of their electrons (equally shared between carbon and hydrogen) compared to those of carbohydrates. A gram of fat oxidized by respiration produces more than twice as much ATP as a gram of carbohydrate. Unfortunately, this also means that a person trying to lose weight must work hard to use up fat stored in the body because so many kilojoules are stockpiled in each gram of fat.

🛠 **Self-Test** (write true if the statement is correct or false if the statement is incorrect).

1. Catabolism is the process of breaking down complex molecules into simpler ones, releasing energy in the form of ATP.
2. Catabolism of carbohydrates involves the breakdown of glucose into pyruvate, which can then enter the citric acid cycle and the electron transport chain.
3. Catabolism of lipids involves the breakdown of triglycerides into glycerol and fatty acids, which can then enter glycolysis and beta-oxidation respectively.
4. Catabolism of proteins involves the breakdown of amino acids into acetyl-CoA, which can then enter the citric acid cycle and the electron transport chain.
5. Catabolism of nucleic acids involves the breakdown of nucleotides into nitrogenous bases, pentose sugars, and phosphate groups, which can then be reused or excreted.

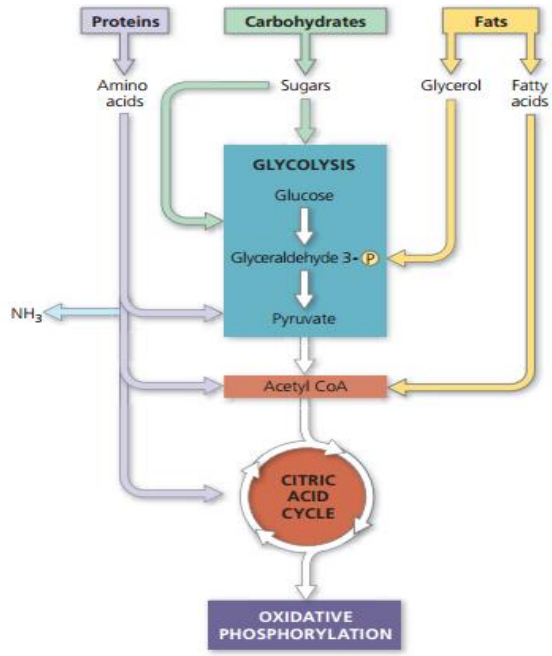


Figure 3. 20. The cataboism of various molecules from food.

Activity 3.7.

Read and prepare a report on:

- At what points in the energy pathway can amino acids from digested proteins enter?
- At what points in the energy pathway can glycerol and fatty acid from digested fat enter?

Two ideas to keep in mind

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

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

Respirometers

Respirometers are fascinating tools used to measure and explore the rate of oxygen consumption during aerobic respiration in living organisms.

Purpose and Function:

A respirometer is designed to measure the rate of respiration by assessing the exchange of oxygen and/or carbon dioxide in a living organism. It allows scientists to investigate how various factors, such as age or exposure to chemicals, impact the rate of respiration

🛠 **Self-Test**

Dear learner, please read the additional material and then provide a report to the tutor with a summary that answers the following questions:

- How do respirometers work? Discuss the principles and mechanisms involved in measuring respiratory rates in organisms using respirometers.
- What are the applications of respirometers in biological research? Explore the various ways respirometers are utilized in experiments and what kind of data they provide.

Fermentation

- What happens in the anaerobic pathway?

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

One type of fermentation is alcohol fermentation. First, pyruvate is decarboxylated (CO_2 leaves) to form acetaldehyde. Hydrogen atoms from NADH + H+ are then used to help convert acetaldehyde to ethanol where NAD+ results.

Facultative anaerobes are organisms that can undergo fermentation when they are deprived of oxygen. Yeast is an example of a facultative anaerobe that will undergo alcohol fermentation (**Figure 3.22**).

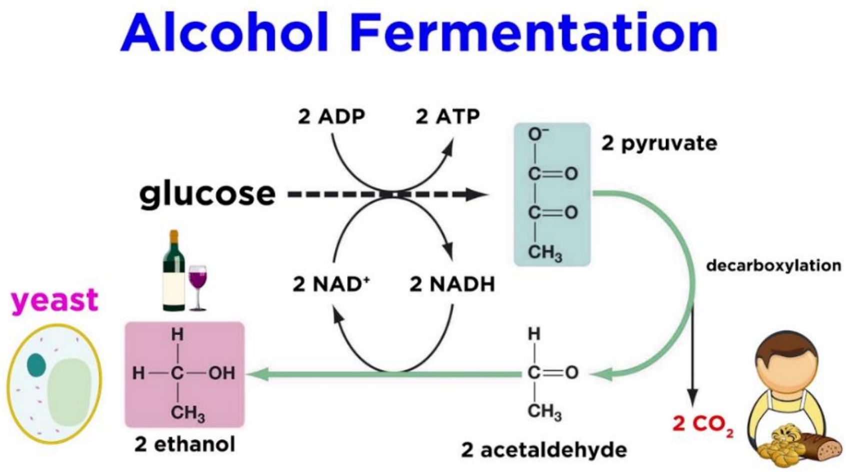


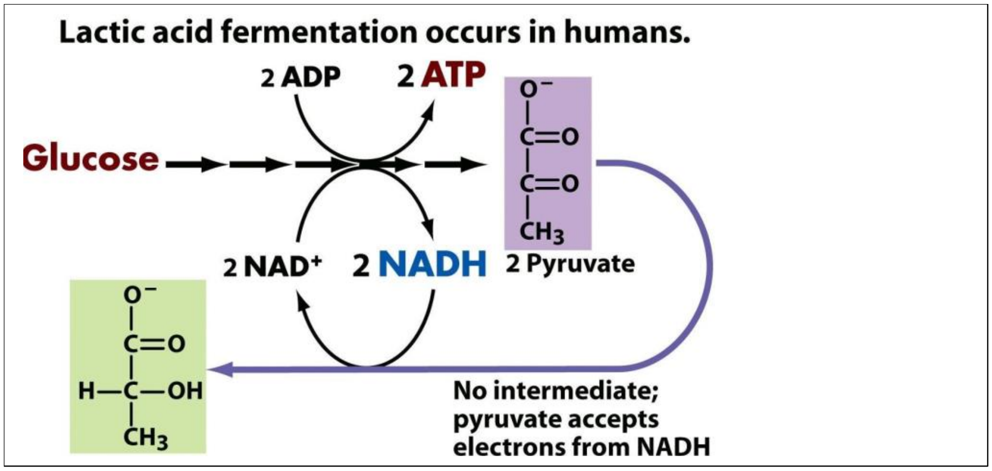
Figure 3.22. Alcohol fermentation

Lactic acid fermentation

What is lactic acid fermentation?

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

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



Activity 3.8. Investigation of the rate of fermentation in yeast
There are many different ways of carrying out this investigation, which range from those using only basic equipment to sophisticated electronically monitored fermenters. The test tube containing the yeast and glucose can be held in a water bath at the desired temperature and the number of bubbles collected per minute recorded.
However, rate of bubbling is not the most accurate way of measuring rate of respiration. Are you sure that all the bubbles are the same volume? The method is improved if the gas syringe replaces test tube of water.

Using this basic equipment, devise experiments to investigate:

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

In your plans, you should make clear:

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

Table 1. Results from Part A.

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

Introduction for Part B – Effect of Temperature on Fermentation

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

Procedure for Part B:

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

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

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

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

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

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

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

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

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

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

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

Table 2. Results from Part B.

Tube #	Temp. °C	Temp. °F	Start Time	End Time	Duration (min)	Volume of CO_2 (ml)	Fermentation rate (ml CO_2/min)
1	0						
2	15						
3	37						
4	70						
1	0→37						
4	70→37						

🛠 <u>Self-Test</u> question (Say True if the statement is correct or False if not)

1. Lactic acid fermentation is a type of anaerobic cellular respiration that produces ATP and lactate from glucose.
2. Lactic acid fermentation occurs only in bacteria and fungi, not in animal cells.
3. Lactic acid fermentation consists of glycolysis followed by the reduction of pyruvate to lactate, regenerating NAD+ for glycolysis.
4. Lactic acid fermentation produces carbon dioxide and ethanol as by-products.
5. Lactic acid fermentation is important for making yogurt, cheese, sourdough bread, and sauerkraut.

Unit Summary

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

- Inside a chloroplast, photosynthesis occurs in two stages: the light-dependent reactions and the light-independent (or Calvin Cycle) reactions.
- The light dependent reactions, a light-dependent series of reactions which occur in the grana, and require the direct energy of light to make energy-carrier molecules (NADPH and ATP) that are used in the light independent phase.
- The light-independent reactions, a light-independent series of reactions which occur in the stroma of the chloroplasts, when the products of the light reaction, ATP and NADPH, are used to make carbohydrates from carbon dioxide (reduction); initially glyceraldehyde 3-phosphate (a 3-carbon atom molecule) is formed.
- Cellular respiration is the process by which cells produce energy from glucose in the form of energy storing compound called ATP(AdenosineTri-Phosphate) for various cellular activities.
- Cellular respiration can take place in the presence as well as in the absence of oxygen. When it utilizes oxygen, it reffered to as aerobic respiration. Aerobic respiration takes place in the mitochondria. It is more efficient as it yields about 36-38ATP per mole gilucose consumed.
- During glycolysis, glucose molecules (six-carbon molecules) are split into two pyruvates (three-carbon molecules) during a sequence of enzyme-controlled reactions. Glycolysis takes place in the cytosol or cytoplasm.
- Anaerobic respiration occurs in the absence of oxygen.
- Without oxygen, pyruvate is converted to lactic acid in animals or ethanol in plants and yeast. It produces only about 10% of the energy released in the complete oxidation of glucose.
- Anaerobic respiration in humans takes place when muscle undergoes extreme contraction as in vigorous exercise. When oxygen is limited the oxidation of NADH to NAD^+ by the electron transport chain is insufficient to maintain glycolysis. Under these conditions NAD^+ is regenerated by the reduction of pyruvate to lactate.

Unit review questions

Choose the correct answer among the alternatives

g. During the light-dependent reactions, which molecule loses an electron?

A. light-harvesting pigment molecule
B. Reaction center pigment molecule
C. NADPH
D. 3-phosphoglycerate

2. Where do the enzymatic reactions of the Calvin cycle take place?

A. stroma of the chloroplast.

B. thylakoid membranes

C. cytoplasm of plant cell

D. outer membrane of the chloroplast

3. Why are C4 plants able to photosynthesize with no apparent photorespiration?

A. They are capable of excluding oxygen from their tissues.

B. They have a mechanism to use PEP carboxylase to initially fix CO_2.

C. They have special adaptations to cold and wet climatic conditions.

D. They are capable of conserving water more efficiently.

4. Which of the following does not occur during cyclic photophosphorylation in cyanobacteria?
A. electron transport through an ETS
B. photosystem I use
C. ATP synthesis
D. NADPH formation

✓ **Self-evaluation check list**

Put a tick (√) against each of the following tasks which you can perform. If you cannot perform any of these tasks, go back and read the lesson for that particular task.

I can:

S.no	Questions	
1	**Discuss the process of energy transformation in cells.**	☐
2	**Summarize the process of photosynthesis using chemical equation.**	☐
3	**Analyze an absorption spectra of chlorophyll a and chlorophyll b using graph.**	☐
4	**Discuss the mechanism as to how CO2 is fixed in C3, C4 plants, and CAM Plants.**	☐

5	**Justify the reason why the rate of photorespiration is less in C4 plants as compared to C3 plants.**	☐
6	**Demonstrate whether or not organic molecules (such as starch) present in leaves.**	☐
7	**Discuss how energy is harvested during aerobic respiration.**	☐
8	**Differentiate between substrate-level phosphorylation and oxidative phosphorylation**	☐
9	**Show the mechanism electron transport system in mitochondria.**	☐
10	**Discuss the significances of fermentation by microorganisms in our daily life.**	☐
11	**Apply the concept of cellular respiration to calculate amount of energy yield from a given molecule of glucose.**	☐
12	**Justify how energy transformations in cells contribute for the maintenance CO2 and O2 balance in the atmosphere.**	☐
13	**Appreciate the mechanism of energy transformation in cells.**	☐

Unit: 3, Assignment Questions -III

Instruction: Dear learner, this is a written assignment to be submitted to your tutor and it is part of the formal assessment. Thus, pay significant attention while doing it.

1. What is the chemical compound that stores the energy captured by photosynthesis? A) Glucose B) Oxygen C) Carbon dioxide D) Water
2. What is the name of the organelle where photosynthesis takes place in plants and algae? A) Mitochondrion B) Chloroplast C) Nucleus D) Ribosome

3. What is the name of the pigment that gives plants their green color and absorbs light energy? A) Carotene B) Anthocyanin C) Chlorophyll D) Hemoglobin
4. What are the two main stages of photosynthesis called? A) Glycolysis and Krebs cycle B) Energy-fixing reaction and carbon-fixing reaction C) Light-dependent reaction and light-independent reaction D) Oxidative phosphorylation and fermentation
5. explain how photosynthesis and cellular respiration are complementary processes that maintain the balance of carbon and oxygen in the biosphere. Include the reactants, products, and locations of each process in your answer.
6. Compare and contrast the different types of photosynthesis (C3, C4, and CAM) in terms of their carbon-fixing mechanisms, advantages, and disadvantages. Provide examples of plants that use each type of photosynthesis and describe how they are adapted to their environments.
7. Describe the structure and function of chloroplasts, the organelles where photosynthesis takes place in plants and algae. Include the roles of the outer and inner membranes, the stroma, the thylakoids, and the grana in your answer.
8. Discuss how light energy is converted into chemical energy during the light-dependent reaction of photosynthesis. Include the roles of chlorophyll, photosystems, electron transport chains, water, oxygen, ATP, and NADPH in your answer.
9. Discuss how carbon dioxide is reduced to glucose during the light-independent reaction of photosynthesis. Include the roles of ATP, NADPH, carbon dioxide, water, ribulose bisphosphate (RuBP), 3-phosphoglyceric acid (3-PGA), glyceraldehyde 3-phosphate (G3P), and glucose in your answer.

==

Unit 3

Activity and Self-Test Answer Key

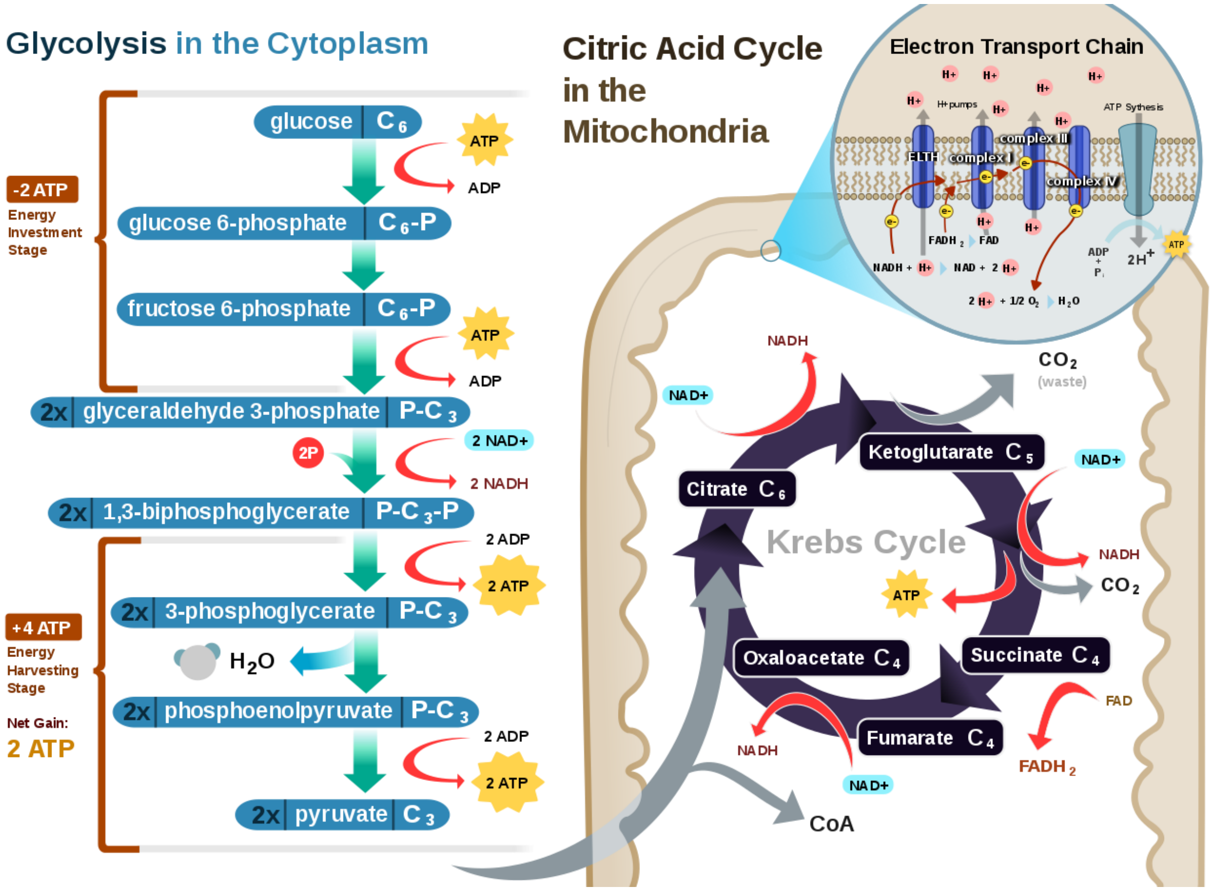
ENERGY TRANSFORMATION

SECTION 3.1. (CELLULAR METABOLISM)

Self-Test Essay (Answer)

1. **Cellular** respiration is indeed a spontaneous process because it involves a decrease in free energy, which is a characteristic of spontaneous reactions. This decrease in free energy is due to the release of energy (negative enthalpy, (\Delta H < 0)) and an increase in disorder (positive entropy, (\Delta S > 0)) within the system.

   The process is also exergonic, meaning it releases energy. In the context of cellular respiration, this energy is released when glucose is broken down into simpler molecules. The energy that is released from glucose during cellular respiration is captured in the form of ATP (adenosine triphosphate), which cells use as a direct source of energy for various functions. Additionally, some of the energy is also stored in the form of NADH and FADH2, which are used later in the electron transport chain to produce more ATP during oxidative phosphorylation



Self-Test Multiple Choice (Answers)

- 1. A, 2. A, 3. B, 4. C, 5. A

SECTION 3.2. (PHOTOSYNTHESIS)

Self-Test Essay (Answers)

1. **Autotrophic organisms** play a crucial role in ecosystems as they form the base of food webs. They are known as producers because they can produce their own food using light, water, carbon dioxide, or other chemicals through processes like photosynthesis or chemosynthesis.

In photosynthesis, autotrophs like plants, algae, and certain bacteria use sunlight to convert water and carbon dioxide into glucose, a type of sugar that provides energy and serves as a building block for other organic compounds. This process not only supports the autotrophs themselves but also supplies energy to the rest of the ecosystem through consumption by herbivores and subsequent predators.

Chemosynthesis, on the other hand, allows some autotrophs to produce food without sunlight. Instead, they use energy from chemical reactions, often involving substances like hydrogen sulfide or methane, to create organic material from inorganic substances1. This is common in extreme environments, such as hydrothermal vents on the ocean floor, where sunlight does not reach.

By converting inorganic substances into organic matter, autotrophs contribute to the flow of energy and cycling of nutrients within an environment. They help maintain the balance of gases in the atmosphere, like oxygen and carbon dioxide, and facilitate the movement of matter through the biosphere. In essence, autotrophs are the foundation upon which the complexity and diversity of life in various ecosystems are built. Without them, higher trophic levels would not have the energy sources necessary to sustain life.

2. **Heterotrophic organisms,** which include all animals, fungi, and many protists and bacteria, rely entirely on autotrophs for their energy needs. This dependence is because heterotrophs cannot synthesize their own food; they must consume or absorb it from other organisms, primarily autotrophs.

Autotrophs, such as plants, algae, and some bacteria, convert sunlight or chemical energy into organic molecules during photosynthesis or chemosynthesis. These organic molecules serve as food not only for the autotrophs themselves but also become the primary source of energy for heterotrophs. Thus, autotrophs are often referred to as **producers and heterotrophs** as consumers within an ecosystem.

The implications of this relationship for ecosystem stability are profound:

- **Energy Transfer Efficiency**: Energy is lost at each trophic level, with only a small percentage passed on to the next level. This limits the number of trophic levels an ecosystem can support and influences the population sizes of organisms at each level.
- **Biodiversity:** The variety of autotrophs affects the diversity of heterotrophs. A greater diversity of producers can support a more complex web of consumers, leading to a more resilient ecosystem.
- **Ecosystem Productivity**: The biomass of autotrophs in an ecosystem directly correlates with its ability to support heterotrophs. Areas with high primary productivity, like tropical rainforests, support a vast array of heterotrophic life.
- **Nutrient Cycling:** Autotrophs play a key role in nutrient cycles by assimilating inorganic nutrients and passing them up the food chain to heterotrophs, which in turn recycle nutrients back into the soil upon death and decomposition.

In essence, the health and stability of ecosystems hinge on the productivity and diversity of autotrophic organisms. Any disruption to the autotroph population, such as through habitat destruction or climate change, can cascade through the food web, affecting all levels of consumers and potentially leading to ecosystem collapse

3. **Photosynthesis** is a fundamental autotrophic process that significantly influences the global carbon cycle. It involves the conversion of carbon dioxide (CO2) and water into organic compounds, using sunlight as an energy source. This process not only provides the basis for life by producing food for autotrophs, but it also has far-reaching effects on atmospheric CO2 levels and climate change.

Here is how photosynthesis influences the global carbon cycle and climate:

- **Carbon Sequestration**: Through photosynthesis, autotrophs remove CO2 from the atmosphere and fix it in the form of organic carbon. This process is a natural form of carbon sequestration, helping to regulate atmospheric CO2 levels.
- **Oxygen Production**: Photosynthesis produces oxygen as a byproduct, which is essential for the survival of aerobic organisms and helps maintain the balance of gases in the atmosphere.
- **Climate Regulation**: By reducing atmospheric CO_2, photosynthesis can mitigate the greenhouse effect. CO_2 is a significant greenhouse gas, and its concentration in the atmosphere is a key factor in global warming. The reduction of CO_2 through photosynthesis helps to stabilize global temperatures.
- **Feedback Loops:** Increased atmospheric CO_2 can enhance photosynthesis in some plants, leading to greater carbon uptake and potentially creating a negative feedback loop that could slow the pace of climate change. However, this effect is limited by other factors such as nutrient availability and water supply.
- **Ecosystem Services**: The organic matter produced by photosynthesis forms the base of the food web, supports biodiversity, and contributes to the productivity and stability of ecosystems.
- **Human Impact:** Human activities, such as deforestation and burning fossil fuels, release large amounts of CO_2 into the atmosphere, disrupting the natural carbon cycle. This has led to a significant increase in atmospheric CO_2 levels, contributing to climate change.

In summary, photosynthesis plays a vital role in regulating the global carbon cycle by controlling the levels of CO_2 in the atmosphere. The balance between photosynthesis and human-induced CO_2 emissions is critical in shaping the Earth's climate and the health of its ecosystems.

2.2.3. External and Internal Structure of the Leaf

Self-Test True or False (Answers)

- 1. True, 2. True, 3. False, 4. True

2.2.4. The site of photosynthesis

Self-Test Essay (Answers)

- Chloroplasts are specialized organelles found in plant cells and green algae. They are the site of photosynthesis, the process by which light energy is converted to chemical energy, resulting in the production of oxygen and energy-rich organic compounds.

Structure of Chloroplasts: Chloroplasts are typically oval-shaped and have a double membrane envelope consisting of an outer and an inner membrane. Between these membranes is an intermembrane space. Inside the inner membrane is the stroma, a dense fluid that contains enzymes, DNA, and ribosomes. Suspended within the stroma are thylakoids, which are flattened sac-like structures that can stack to form grana. The thylakoids contain chlorophyll, the green pigment that captures light energy for photosynthesis.

Location in Plant Cells: Chloroplasts are found in all green tissues of plants but are particularly concentrated in the parenchyma cells of the leaf mesophyll. This location is optimal for capturing sunlight. In vascular plants and green algae, chloroplasts can circulate within the cells to optimize light absorption.

Role in Photosynthesis: During photosynthesis, chloroplasts absorb light energy through chlorophyll and convert it into chemical energy in the form of ATP (adenosine triphosphate) and NADPH (nicotinamide adenine dinucleotide phosphate). This energy is then used in the Calvin cycle, which takes place in the stroma, to convert carbon dioxide and water into glucose and other carbohydrates. Oxygen is released as a byproduct of this process.

In summary, chloroplasts are essential for photosynthesis, providing both the location and the machinery needed for converting light energy into chemical energy, which is vital for the growth and survival of plants and the functioning of ecosystems.

- Check **Figure 3.3** on your module.
- When a photon of light energy is absorbed by a chlorophyll molecule, it triggers a fascinating process. Here's what happens:
  1) Photon Absorption: A photon, which is a particle of light, collides with the chlorophyll molecule.
  2) Excitation of Electron: The energy from the photon is transferred to an electron within the chlorophyll molecule, causing this electron to become "excited" and move to a higher energy state.
  3) Energy Transfer Cascade: This excited state is temporary. The high-energy electron is then transferred from the chlorophyll to a series of proteins embedded in the thylakoid membrane known as the electron transport chain.
  4) Chemical Energy Production: As the electron moves down the electron transport chain, its energy is used to pump protons across the thylakoid membrane, creating a proton gradient that is used to produce ATP. Eventually, the electron is used to reduce NADP+ to NADPH, which are both crucial molecules for the Calvin cycle, where the actual synthesis of glucose occurs.

     This process is integral to the light-dependent reactions of photosynthesis, where light energy is converted into chemical energy, which is then used to fuel the life-sustaining processes of the plant.
- The chloroplast and its internal structures, including the stroma, grana, thylakoids, and photosystems, are all interconnected and play specific roles in the process of photosynthesis:

- **Chloroplast:** This is the organelle within plant cells that houses the entire photosynthetic machinery. It has a double membrane structure with an intermembrane space.

- **Stroma:** The stroma is the fluid-filled space within the chloroplast that surrounds the thylakoids and grana. It contains enzymes necessary for the light-independent reactions of photosynthesis (the Calvin cycle), chloroplast DNA, and ribosomes.
- **Grana:** These are stacks of thylakoids, which are connected to each other by intergranal or stromal thylakoids. The grana are where the light-dependent reactions of photosynthesis primarily occur.
- **Thylakoids:** Thylakoids are membrane-bound compartments inside the chloroplast. They contain chlorophyll and other pigments that capture light energy. The thylakoid membrane houses the photosystems and the electron transport chain involved in the light-dependent reactions.
- **Photosystems:** These are complexes of proteins and pigments (including chlorophyll) embedded in the thylakoid membranes. There are two types of photosystems: Photosystem I (PSI) and Photosystem II (PSII). They work together to absorb light energy and convert it into chemical energy in the form of ATP and NADPH. Photosystems are crucial for the initiation of the light-dependent reactions.

  In summary, the chloroplast is the cell organelle where photosynthesis takes place. The stroma provides the environment for the light-independent reactions, while the grana and thylakoids facilitate the light-dependent reactions. The photosystems embedded in the thylakoid membranes capture light energy to drive the synthesis of ATP and NADPH, which are then used in the Calvin cycle within the stroma to produce glucose from CO2 and water

- The interaction between the reaction center chlorophyll and the antenna pigments in a photosystem is a key part of the light-dependent reactions of photosynthesis. Here’s how they work together:

1) **Light Absorption**: Antenna pigments, which include chlorophylls and other accessory pigments, absorb photons of light across a range of wavelengths. This absorption raises the energy level of electrons within these pigments.
2) **Energy Transfer:** Once the antenna pigments have absorbed light energy, they transfer this energy through resonance energy transfer to the reaction center chlorophyll. This process is efficient and happens very quickly.
3) **Charge Separation**: The reaction center chlorophyll, now excited by the energy it has received, can transfer an electron to a nearby acceptor molecule. This starts the electron transport chain and leads to the synthesis of ATP and NADPH, which are used in the Calvin cycle to fix carbon dioxide into sugars.

The arrangement of antenna pigments around the reaction center chlorophyll allows for a broad spectrum of light to be absorbed and funneled efficiently to the reaction center, optimizing the energy capture for photosynthesis. This system ensures that even under low light conditions, or when light is only available at certain wavelengths, the plant can still perform photosynthesis effectively. The efficiency of this energy transfer is crucial for the survival of plants and the ecosystems that depend on them.

Self-Test Multiple Choice (Answers)

- 1. B, 2. C

2.2.3.Photosynthetic pigments

Self-Test Essay (Answers)

1. The color of light that is least effective in driving photosynthesis is **green**. This is because chlorophyll, the main pigment involved in photosynthesis, does not absorb green light well. Instead, it reflects **green light**, which is why plants appear green to our eyes. Chlorophyll absorbs light most efficiently in the **red**

and blue parts of the spectrum, and these wavelengths are used to drive the photosynthetic process. **Green light**, having a wavelength range that is not efficiently absorbed, contributes less to photosynthesis compared **to red and blue light**.

2. Light possesses several physical properties that define its behavior and effects:

- **Wave-Particle Duality**: Light exhibits both wave-like and particle-like properties. It can spread out like a wave and interact with matter as if it were a particle known as a photon.
- **Electromagnetic Radiation**: Light is a form of electromagnetic radiation, which means it is composed of electric and magnetic fields that oscillate perpendicular to each other and to the direction of propagation.
- **Speed:** In a vacuum, light travels at a constant speed of approximately 299,792,458 meters per second.
- **Wavelength and Frequency**: Light has a wavelength and frequency, which are inversely related. The wavelength is the distance between successive peaks of the wave, while frequency is the number of waves that pass a point in one second.

The relationship between the wavelength of light ((\lambda)) and its energy ((E)) is given by the equation:

[E = \frac{hc}{\lambda}]

Where (h) is Planck's constant ((6.626 \times 10^ {-34}) Joule seconds) and (c) is the speed of light in a vacuum3. This equation shows that energy and wavelength are inversely proportional; as the wavelength increases, the energy decreases, and vice versa. Therefore, light with a shorter wavelength, like ultraviolet light, has more energy than light with a longer wavelength, like infrared light

<u>Self-Test True or False (Answers)</u>

- 1. True, 2. False, 3. False, 4. False, 5. True

<u>Activity 3.4. (Answer)</u>

The combined absorption spectra of chlorophylls a and b play a crucial role in photosynthesis. When we look into the significance and explore why their approximate match with the action spectrum of photosynthesis matters:

(1). Efficient Light Harvesting:

- Chlorophylls are the primary pigments responsible for capturing light energy during photosynthesis.
- Their absorption spectra cover a wide range of wavelengths, including blue and red light.
- By having both chlorophyll a and chlorophyll b, plants can efficiently harvest light across different parts of the visible spectrum.
- Chlorophyll a absorbs slightly different wavelengths than chlorophyll b, allowing them to complement each other.

(2). Matching the Action Spectrum:

- The action spectrum represents the efficiency of photosynthesis at various wavelengths of light.
- Remarkably, the combined absorption spectra of chlorophylls a and b roughly align with the action spectrum.
- This alignment ensures that plants can effectively utilize available light energy for photosynthesis.
- The peaks in the absorption spectra correspond to wavelengths where photosynthesis is most efficient.

(3). Photosynthesis Efficiency:

- If chlorophyll a and chlorophyll b had identical absorption spectra, photosynthesis might not be more efficient.
- Having distinct absorption peaks allows plants to capture light energy from a broader range of wavelengths.
- Chlorophyll b's absorption in the blue region complements chlorophyll a's absorption in the red region.
- This synergy enhances overall photosynthetic efficiency by maximizing light absorption.

In summary, the combined absorption spectra of chlorophylls a and b are finely tuned to match the action spectrum of photosynthesis. Their cooperative interaction ensures optimal light harvesting and efficient energy conversion in plants.

ABSORPTION SPECTRA OF PHOTOSYNTHETIC PIGMENTS

<u>Self-Test Matching (Answers)</u>

- A) Absorption spectrum – 2, B) Chlorophyll - 3 ,C) Mesophyll - 5 ,D) Red edge – 4, E) Carotenoid – 1

2.2.4. Light-dependent and light-independent reactions

<u>Self-Test Essay (Answers)</u>

1. Photosynthesis consists of two main stages: the light-dependent reactions and the carbon fixation reactions, also known as the Calvin cycle. Here's how they differ:

Light-Dependent Reactions:

- **Location:** Occur in the thylakoid membranes of chloroplasts.
- **Energy Source**: Powered by sunlight, which is absorbed by chlorophyll and other pigments within the photosystems.
- **Primary Events**: Involve the conversion of light energy into chemical energy (ATP and NADPH), the splitting of water molecules to release oxygen, and the transfer of electrons through the electron transport chain.
- **Output:** Produce ATP and NADPH, which are used in the Calvin cycle.

Carbon Fixation Reactions (Calvin Cycle):

- **Location:** Take place in the stroma of chloroplasts2.
- **Energy Source**: Do not directly use light energy; instead, they use the ATP and NADPH generated by the light-dependent reactions2.
- **Primary Events**: Involve the fixation of atmospheric CO2 into organic molecules, followed by a series of reactions that convert these molecules into glucose.
- **Output:** Produce glucose and other carbohydrates that can be used by the plant for energy and growth.

In essence, the light-dependent reactions capture energy from sunlight to produce the energy carriers ATP and NADPH, while the Calvin cycle uses these carriers to fix carbon dioxide into sugars, thus forming the basis of the food chain. Both stages are interconnected and essential for the sustenance of life on Earth.

2. The carbon fixation reactions, also known as the Calvin cycle, are heavily dependent on the light-dependent reactions of photosynthesis for two main reasons:
    1) **Provision of Energy**: The light-dependent reactions produce ATP (adenosine triphosphate), which serves as the energy currency for the Calvin cycle. The energy from ATP is used to drive the endergonic reactions in the Calvin cycle.
    2) **Supply of Reducing Power**: The light-dependent reactions also generate NADPH (nicotinamide adenine dinucleotide phosphate), which acts as a reducing agent. NADPH provides the high-energy electrons needed to convert carbon dioxide (CO2) into glucose during the Calvin cycle.

Without the ATP and NADPH produced by the light-dependent reactions, the Calvin cycle would not have the energy or reducing power to synthesize organic molecules from CO2. Therefore, even though the Calvin cycle does not require light directly, it is indirectly dependent on the light-dependent reactions for the necessary energy and electron carriers.

PHOTORESPIRATION

Self-Test Multiple Choice (Answers)

- 1. D, 2. A, 3. B, 4. B, 5. B

Self-Test Essay (Answers)

1. Rubisco, or ribulose-1,5-bisphosphate carboxylase/oxygenase, is an enzyme that plays a dual role in photosynthesis and photorespiration. Here's how it acts differently in these processes:

Carboxylation (Making RuBP):

- In the Calvin cycle of photosynthesis, rubisco catalyzes the carboxylation of ribulose-1,5-bisphosphate (RuBP), which is the addition of carbon dioxide (CO_2) to RuBP.
- This reaction is the first step in the Calvin cycle and results in the formation of two molecules of 3-phosphoglycerate (3PGA), which are then used to build organic molecules like glucose.

Oxygenation (Oxidizing RuBP):

- Rubisco also has oxygenase activity, meaning it can bind to oxygen (O_2) in a process known as photorespiration.
- When O_2 is abundant, rubisco catalyzes the oxidation of RuBP, leading to the production of one molecule each of phosphoglycerate and phosphoglycolate.
- This reaction is considered wasteful because it does not contribute to sugar production and instead leads to the loss of already-fixed carbon as CO_2.

In summary, rubisco can act to make RuBP by catalyzing the carboxylation reaction in the Calvin cycle, or it can oxidize RuBP by binding to oxygen during photorespiration. The balance between these two activities is influenced by the relative concentrations of CO_2 and O_2, as well as environmental conditions such as temperature.

2. The carbon fixation pathways in C3, C4, and CAM plants represent different adaptations to photosynthesis, each with unique features suited to their environments. Here's a comparison of their functions:

C3 Pathway:

- Most common and found in about 85% of plant species, including trees and temperate grasses.
- Carbon fixation occurs in the Calvin cycle, where CO_2 is directly fixed to RuBP, forming a three-carbon compound, 3-phosphoglycerate (3-PGA).

- High rate of photorespiration, which can be wasteful, especially under high temperatures and light intensities.

C4 Pathway:

- Adapted to high light intensities, high temperatures, and dry conditions, found in plants like corn and sugarcane.
- Carbon fixation is divided into two steps: CO2 is first fixed into a four-carbon compound in mesophyll cells, and then transported to bundle-sheath cells where the Calvin cycle occurs.
- Minimizes photorespiration by concentrating CO2 around rubisco, making the process more efficient under stressful conditions.

CAM Pathway:

- Found in succulents and cacti adapted to very arid conditions.
- Stomata open at night to fix CO2 into organic acids, which are stored until daylight when the Calvin cycle occurs.
- Very low rate of photorespiration and excellent water-use efficiency, as stomata are closed during the day to reduce water loss.

In summary, C3 plants fix carbon directly through the Calvin cycle, C4 plants have a spatial separation of initial CO2 fixation and the Calvin cycle, and CAM plants have a temporal separation, fixing CO2 at night and using it during the day. Each pathway represents a different strategy to optimize carbon fixation under varying environmental conditions.

3.2.5. Contributions of Photosynthesis for the Continuity of Life, for O2 And Co2 Balance and Global Warming

<u>Self-Test True or False (Answers)</u>

- 1. False, 2. True, 3. False, 4. True, 5. False

<u>Review Question (Answers)</u>

- 1. C, 2; A; 3. C; 2. C ; 3. A; 4. B; 5. C; 6. C; 7. C; 8. B; 9. D; 10. B; 11. D ;12. C; 13. D; 14. D ;15. A; 16. A

Section 3.3. (**CELLULAR RESPIRATION)**

Self-Test Multiple Choice (Answers)

- 1. A, 2. B, 3. C, 4. A, 5. D

3.3.1. THE SITE OF CELLULAR RESPIRATION

Self-Test Essay (Answers)

1) The starting material for cellular respiration is **glucose**. This glucose is broken down during the process of cellular respiration to produce ATP, the energy currency of the cell.

2) The energy from nutrient molecules is temporarily stored in the form of high-energy compounds like ATP (adenosine triphosphate) and NADH (nicotinamide adenine dinucleotide). These molecules act as energy carriers and are used by cells to perform various functions. ATP, in particular, is often referred to as the energy currency of the cell because it can be used to drive many cellular processes. Additionally, energy can be stored in molecules like glycogen and triglycerides, which contain energy-rich covalent bonds that can be broken down to release energy when needed.

3) Cellular respiration begins in the cytoplasm of the cell, where the process of **glycolysis** takes place. During glycolysis, glucose is broken down into pyruvate, which is then transported into the mitochondria for **further stages of cellular respiration.**

4) **Oxygen** plays a crucial role in cellular respiration as the **final electron** acceptor in the electron transport chain within the **mitochondria**. During aerobic respiration, electrons are transferred through a series of molecules to oxygen, which combines with **hydrogen** ions to form **water**. This process releases energy that is used to **produce ATP**, the primary energy source for cells. Without oxygen, the electron transport chain would halt, and cells would have to rely on less efficient anaerobic pathways.

Activity 3.5. (Answer)

1. The overall equation that describes cellular respiration is:

$$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O + \text{Energy (ATP)}$$

This equation summarizes the process of breaking down glucose in the presence of oxygen to produce carbon dioxide, water, and energy in the form of ATP.

Substrate-level phosphorylation is a type of ATP production that occurs when a phosphate group is directly transferred from a phosphorylated compound (substrate) to ADP, forming ATP. This occurs during two stages of cellular respiration:

- **Glycolysis**: where 4 ATP molecules are produced, but the net gain is 2 ATP because 2 are used up in the initial steps of glycolysis.
- **Citric Acid Cycle (Krebs Cycle)**: specifically during the conversion of succinyl-CoA to succinate, which generates GTP that can be readily converted to ATP, resulting in a total of 2 ATP per glucose molecule since the cycle runs twice for each glucose molecule.

Oxidative phosphorylation is the process where ATP is formed as a result of the transfer of electrons from NADH and $FADH_2$ to oxygen by a series of electron carriers. This occurs in the mitochondria during the electron transport chain and chemiosmosis, and it produces the majority of ATP in cellular respiration - approximately 34 ATP molecules from one molecule of glucose.

Self-Test Multiple Choice (Answers)

- 1. A, 2. B, 3. A, 4. C, 5. B

KREB CYCLE

Activity 3.6. Answers

1. Before pyruvic acid enters the Krebs cycle, it undergoes a crucial transformation in a process known as pyruvate oxidation. During this process, pyruvate, which is a three-carbon molecule produced at the end of glycolysis,

is converted into a two-carbon molecule called acetyl coenzyme A (acetyl CoA). Here's what happens in the steps of pyruvate oxidation:

- **Decarboxylation:** A carboxyl group (-COOH) is removed from pyruvate, releasing a molecule of carbon dioxide (CO_2).
- **Oxidation:** The remaining two-carbon fragment is oxidized, resulting in the reduction of NAD^+ to NADH, which captures high-energy electrons.

  Formation of Acetyl CoA: Finally, the oxidized two-carbon molecule is attached to Coenzyme A, forming acetyl CoA.

The acetyl CoA then enters the Krebs cycle, where it combines with oxaloacetate to begin the cycle of reactions that generate ATP and other high-energy molecules like NADH and $FADH_2$. The pyruvate dehydrogenase complex, a group of enzymes that facilitate these reactions, catalyzes this step.

2. The Krebs cycle, also known as the citric acid cycle, takes place in the mitochondrial matrix of eukaryotic cells. In prokaryotic cells, which lack mitochondria, the Krebs cycle occurs in the cytoplasm. The mitochondrial matrix provides the necessary environment and enzymes for the complex reactions of the Krebs cycle to occur.
3. The Krebs cycle, also known as the citric acid cycle, generates CO_2, ATP, NADH, and $FADH_2$ through a series of reactions that occur in the mitochondrial matrix. Here's a simplified overview of how each of these molecules is produced during the cycle:
   - **Formation of Citrate**: Acetyl CoA combines with oxaloacetate to form citrate, starting the cycle.
   - **Release of CO_2:** Citrate is rearranged and oxidized, releasing two molecules of CO_2 through decarboxylation steps as it is transformed back into oxaloacetate.
   - **Production of NADH and $FADH_2$**: Several steps involve the oxidation of intermediates, where NAD^+ and FAD are reduced to NADH and $FADH_2$,

respectively. These molecules carry high-energy electrons to the electron transport chain.

- **Generation of ATP:** One molecule of ATP (or GTP in some organisms) is produced directly in the cycle through substrate-level phosphorylation.

  Overall, for each acetyl CoA that enters the cycle, two molecules of CO2 are released, and three NADH, one FADH2, and one ATP (or GTP) are produced. Since two molecules of acetyl CoA are produced from each glucose molecule during glycolysis, the cycle must turn twice for each glucose molecule, doubling these yields.

THE ENERGY BUDGET OF ONE GLUCOSE MOLECULE

<u>Self-Test Essay (Answers)</u>

4. The electrons captured in NADH and FADH2 during the Krebs cycle are transferred to the electron transport chain (ETC), which is located in the inner mitochondrial membrane. Here's a step-by-step process of what happens to these electrons:
    1) **Electron Transport Chain**: NADH and FADH2 donate their electrons to the ETC, a series of protein complexes and small organic molecules embedded in the inner mitochondrial membrane.
    2) **Energy Release**: As electrons move through the ETC, they release energy in a controlled manner.
    3) **Proton Pumping**: The energy released is used to pump protons (H+) from the mitochondrial matrix into the intermembrane space, creating a proton gradient across the membrane.
    4) **ATP Synthesis**: The protons flow back into the matrix through ATP synthase, a protein that uses the proton gradient to generate ATP from ADP and inorganic phosphate—this process is known as oxidative phosphorylation.
    5) **Water Formation**: At the end of the ETC, the electrons are combined with oxygen (the final electron acceptor) and protons to form water.

This process is highly efficient and generates most of the ATP produced in cellular respiration

5. **The electron transport system (ETS)** is a crucial component of cellular respiration, where oxidation and reduction reactions play a pivotal role. **Here's a simplified explanation**:
   1) Oxidation refers to the loss of electrons from a molecule, while reduction refers to the gain of electrons.
   2) In the ETS, a series of redox reactions occur within the inner mitochondrial membrane, involving the transfer of electrons through a chain of protein complexes and electron carriers.
   3) Electrons are donated by reduced molecules like NADH and FADH2, which are oxidized in the process, reverting to NAD+ and FAD respectively.
   4) As electrons move down the chain, they go from a higher to a lower energy state, releasing energy that is used to pump protons (H+) across the membrane, creating a proton gradient.
   5) This gradient generates an electrochemical potential, termed the proton-motive force.
   6) The flow of protons back across the membrane through ATP synthase drives the synthesis of ATP from ADP and inorganic phosphate, a process known as chemiosmosis.
   7) Oxygen acts as the final electron acceptor at the end of the ETS, combining with electrons and protons to form water.

This intricate interplay of oxidation and reduction reactions not only facilitates the production of ATP but also maintains the flow of electrons, essential for the cell's energy supply.

6. The proton (H+) gradient is the link between the electrons from the Krebs cycle and ATP formation through a process called oxidative phosphorylation. **Here's how it works**:

a. **Electrons from the Krebs Cycle:** The Krebs cycle generates high-energy electron carriers, namely NADH and FADH2. These carriers are loaded with electrons derived from the food molecules that were broken down during earlier stages of cellular respiration.
b. **Electron Transport Chain (ETC):** These electrons are transferred to the electron transport chain, a series of protein complexes located in the inner mitochondrial membrane. As electrons pass through the ETC, they move from a higher to a lower energy state.
c. **Proton Pumping:** The energy released from the electrons moving through the ETC is used to pump protons (H+) from the mitochondrial matrix into the intermembrane space, creating a proton gradient.
d. **Chemiosmosis:** This proton gradient creates a potential energy difference across the membrane. Protons flow back into the matrix through ATP synthase, a protein that uses the energy of this flow to synthesize ATP from ADP and inorganic phosphate.
e. **ATP Formation:** The flow of protons through ATP synthase drives the production of ATP. This is the final step where the energy from the electrons, originally from the Krebs cycle, is captured in the form of ATP.

In summary, the proton gradient is essential for converting the energy carried by electrons from the Krebs cycle into a form that the cell can use, which is ATP. This process is efficient and allows for the generation of a significant amount of ATP, which is vital for various cellular processes.

7. The efficiency of ATP in capturing the energy from a glucose molecule is quite remarkable. When one mole of glucose is metabolized under standard conditions, it releases about **686 kcal/mol** of energy. However, not all of this energy is captured in the form of ATP; some is lost as heat.

   The process of cellular respiration, which includes glycolysis, the Krebs cycle, and the electron transport chain, produces **ATP**. The efficiency of this process can be calculated by comparing the energy stored in the bonds of ATP with the energy released from glucose. Under standard conditions, the efficiency is approximately **38.3%.** This means that about **38.3%** of the energy released from glucose is captured in the high-energy bonds of **ATP**.

However, in the cellular environment, conditions are not standard. The concentration of ATP is often higher than that of ADP, which increases the free energy of **ATP hydrolysis**. Considering this, the efficiency of energy extraction from glucose in cells is approximately **50%.** This is significantly higher than the efficiency of an electric motor or gasoline engine, which is about **10% to 20%.**

In summary, the cell's ability to capture energy from glucose in the form of ATP is highly efficient, especially when compared to man-made energy conversion systems.

8. The theoretical estimate of ATP production from one glucose molecule during aerobic respiration is a complex calculation that involves several steps in cellular respiration.

Here is a simplified breakdown:

- **Glycolysis:** Each glucose molecule yields **2ATPs** directly through substrate-level phosphorylation and **2NADH** molecules. Each NADH can theoretically produce **3 ATPs** when it donates electrons to the electron transport chain (ETC), adding up to **6 ATPs**.
- **Pyruvate Oxidation**: Each pyruvate molecule (2 per glucose) produces **1 NADH**, which again contributes **3ATP**s each to the ETC, totaling **6 ATPs**.
- **Krebs Cycle**: Each turn of the Krebs cycle (2 per glucose) produces 1 ATP (or GTP), **3 NADH**, and **1FADH2.** The **3NADH** from each turn contribute **9 ATPs** (3 ATPs each), and the **1FADH2** contributes **2ATPs**, totaling **12 ATPs** per turn or **24ATPs** for both turns.

Adding these up:

- **Glycolysis:** 2 ATP + 6 ATP (from NADH) = 8 ATP
- **Pyruvate Oxidation**: 6 ATP (from NADH)
- **Krebs Cycle:** 2 ATP + 24 ATP (from NADH and FADH2) = **26 ATP**

The total theoretical yield is 8 ATP (Glycolysis) + 6 ATP (Pyruvate Oxidation) + 26 ATP (Krebs Cycle) = **40 ATP**.

However, there are a couple of considerations:

- The transport of NADH from glycolysis into the mitochondria consumes ATP, which may reduce the yield by **1ATP** per **NADH**.
- The P/O ratio (the number of ATPs produced per oxygen atom reduced) for NADH and FADH2 is not always a whole number and can vary.

  Considering these factors, the theoretical yield is often stated as **36 ATPs** per glucose molecule. This is a simplified estimate, and actual cellular conditions can affect the efficiency of ATP production.

9. The number **36 ATP per glucose** molecule is an approximate due to several factors that can influence the actual yield of ATP during cellular respiration:
   - **Variable P/O Ratios**: The P/O ratio, which is the number of ATP molecules produced per pair of electrons passing through the electron transport chain, is not always a whole number. It can vary depending on the organism and the conditions within the mitochondria.
   - **Proton Leak**: Some protons may leak across the mitochondrial membrane without contributing to ATP synthesis, which can reduce the efficiency of ATP production.
   - **Transport of NADH**: In eukaryotic cells, the NADH produced in glycolysis must be transported into the mitochondria. This transport can consume ATP, which would reduce the net yield.
   - **Substrate-Level Phosphorylation**: The ATP yield from substrate-level phosphorylation during glycolysis and the Krebs cycle is direct and does

not involve the electron transport chain. This can lead to variations in the total ATP count.

- **Use of FADH2 and NADH**: FADH2 and NADH donate electrons to different points in the electron transport chain, with FADH2 contributing less to the proton gradient than NADH, which affects the total ATP yield.
- **Efficiency of ATP Synthase**: ATP synthase may not always work at maximum efficiency, and the actual number of protons required to synthesize one ATP molecule can vary.
- **Cellular Conditions**: The actual yield of ATP can also depend on the specific cellular conditions, such as the availability of oxygen, the type of cell, and the metabolic demands at the time.

Due to these and other factors, the number of ATP molecules produced per glucose molecule can fluctuate, making **36 ATP** a useful but approximate average for the purposes of calculation and comparison.

Energy from non-carbohydrate sources (Self-Test)

- 1. True, 2. True, 3. True, 4. False, 5. True

Activity 3.7. Answers

1. Amino acids from digested proteins can enter the energy pathway at several points, depending on their structure and the body's needs. Here are the primary entry points:
    - **Glycolysis**: Some amino acids can be converted into pyruvate or intermediates of glycolysis, such as 3-phosphoglycerate or phosphoenolpyruvate, and then enter the pathway for ATP production.
    - **Krebs Cycle**: Other amino acids can be transformed into compounds that directly enter the Krebs cycle, such as oxaloacetate or a-ketoglutarate, contributing to the cycle and leading to ATP generation.
    - **Acetyl-CoA**: Certain amino acids are converted into acetyl-CoA, which is the entry molecule for the Krebs cycle and is central to the metabolism of carbohydrates, fats, and proteins.

These entry points allow amino acids to be used flexibly by the body, either for energy production, synthesis of new proteins, or for other metabolic needs. The ability to utilize amino acids in this way is crucial for maintaining energy balance, especially during periods when carbohydrates are scarce.

2. Glycerol and fatty acids from digested fats enter the energy pathway at different points:
   1) **Glycerol**: It is converted into glyceraldehyde-3-phosphate (G3P), which enters the glycolysis pathway. G3P can then be further metabolized to produce ATP and other intermediates that feed into the Krebs cycle.
   2) **Fatty Acids**: a process called beta-oxidation into acetyl-CoA, which enters the Krebs cycle, breaks them down. Acetyl-CoA is a key metabolite that can be used to generate ATP or to synthesize other compounds as needed by the cell.

   These entry points allow for the flexible use of different macronutrients in the energy-producing pathways of the cell, depending on the body's energy requirements and the availability of nutrients.

RESPIROMETERS

<u>Self-Test Essay (Answers)</u>

1. Respirometers are devices used to measure the rate of respiration in organisms by tracking the exchange of oxygen and carbon dioxide. The principles and mechanisms involved in their operation are as follows:

Principles:

- **Gas Exchange Measurement**: Respirometers measure the rate of oxygen consumption and/or carbon dioxide production, which are indicators of respiration rates.

- **Closed System**: In a closed system, the organism is placed in a sealed container, and changes in gas composition over time reflect the organism's metabolic activity.
- **Open System**: In an open system, air flows through the chamber, constantly replenishing oxygen and removing carbon dioxide produced by the organism.

Mechanisms:

- **Manometry**: A common method involves using a manometer to detect changes in gas volume or pressure within the respirometer. As the organism consumes oxygen, the pressure decreases, which can be measured and correlated with the rate of respiration.
- **Carbon Dioxide Absorption**: Often, a substance like the one soda lime is included to absorb the carbon dioxide produced, ensuring that any change in gas volume is due to oxygen consumption alone.
- **Temperature Control:** The respirometer is usually placed in a temperature-controlled environment to maintain consistent metabolic rates during the measurement.

By analyzing the data collected from respirometers, researchers can study how various factors, such as temperature, chemicals, or the age of the organism, affect the rate of respiration. This information is crucial for understanding metabolic processes and can be applied in fields ranging from environmental science to medical research.

2. Respirometers are versatile tools in biological research with a range of applications. Here are some ways they are utilized:
    1) **Wastewater Treatment**: Respirometers can monitor oxygen uptake in wastewater treatment processes to assess the biodegradation of organic matter and determine biokinetic coefficients.

2) **Ecological Studies:** They help in understanding the energy requirements of different species and their responses to environmental changes.
3) **Metabolic Research**: Respirometers measure rates of cellular respiration under various conditions, providing insights into metabolic processes and energy expenditure.
4) **Toxicity Testing**: By measuring the respiratory response of organisms to various substances, respirometers can be used to assess the toxicity of chemicals and pollutants.
5) **Physiological Studies:** They are used to study the effects of physical activity, diet, or disease on the metabolic rate of organisms.

The data provided by respirometers typically include oxygen consumption rates, carbon dioxide production rates, and respiratory quotients, which are valuable for understanding the metabolic activities of organisms under study.

Activity 3.8. (Answers)

To investigate the rate of fermentation in yeast, you can design experiments that measure the production of carbon dioxide as an indicator of fermentation activity. Here is a basic outline for your experiments:

1. Effect of Temperature on Fermentation Rate:

- **Independent Variable**: Temperature of the water bath (e.g., 20°C, 30°C, 40°C).
- **Dependent Variable**: Rate of carbon dioxide production measured by a gas syringe.
  - **Controlled Variables**: Type and concentration of sugar, volume of yeast suspension, and duration of the experiment.
  - **Why to control**: To ensure that any changes in the rate of fermentation are due to temperature changes only.

- How to control: Use a water bath to maintain constant temperatures and keep other conditions identical across all trials.

2. Effect of Different Sugars on Fermentation Rate:

- **Independent Variable**: Type of sugar (e.g., glucose, fructose, sucrose).
- **Dependent Variable**: Rate of carbon dioxide production.
- **Controlled Variables**: Temperature, concentration of sugar, volume of yeast suspension, and duration of the experiment.
  - **Why to control**: Different sugars may be metabolized at different rates by yeast, affecting the rate of fermentation.
  - **How to control**: Use the same concentration of each sugar and maintain other conditions constant.

3. Effect of Substrate Concentration on Fermentation Rate:

- **Independent Variable**: Concentration of sugar (e.g., 5%, 10%, 15%).
- **Dependent Variable**: Rate of carbon dioxide production.
- **Controlled Variables**: Temperature, type of sugar, volume of yeast suspension, and duration of the experiment.
  - **Why to control:** Different concentrations can affect the osmotic pressure and yeast metabolism.
  - **How to control**: Adjust the amount of sugar while keeping the total solution volume constant.

As fermentation proceeds, the yeast cells consume sugars and produce ethanol and carbon dioxide. The concentration of sugar will decrease, while the concentrations of ethanol and carbon dioxide will increase. Sophisticated fermenters can monitor these changes in real-time, providing a detailed view of the fermentation kinetics.

Remember to include replicates for each condition to ensure reliability and use appropriate statistical methods to analyze your data. Good luck with your experiments

Fermentation (Self-Test)

- 1. True, 2. False, 3. True, 4. False, 5. True