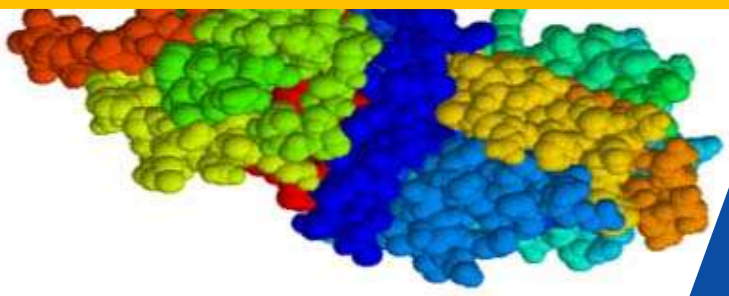
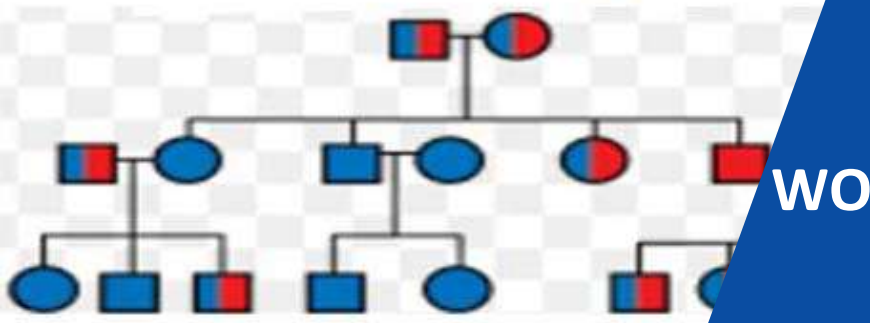
RQF LEVEL 4





GENAB402

AGR, FOP, ANH, FOR, WOT, WIR, LET, FBO, TOR, FPA

APPLIED BIOLOGY

TRAINEE'S MANUAL

October, 2024

DEMONSTRATE KNOWLEDGE OF GENERAL BIOLOGY

KOICA Korea International Cooperation Agency

TQUM TVET Quality Management Project

2024

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Copies available from:

- *HQs: Rwanda TVET Board-RTB*
- *Web: www.rtb.gov.rw*
- **KIGALI-RWANDA**

Original published version: October 2024

ACKNOWLEDGEMENTS

The publisher would like to thank the following for their assistance in the elaboration of this training manual:

Rwanda TVET Board (RTB) extends its appreciation to all parties who contributed to the development of the trainer's and trainee's manuals for the TVET Certificate IV in Agriculture, Food Processing, Animal Health, Forestry, Wood Technology, Water and Irrigation, Leather Technology, Food and Beverage Operations, Tourism and Fine and Plastic Arts
, specifically for the module "**Applied Biology**".

We extend our gratitude to KOICA Rwanda for its contribution to the development of these training manuals and for its ongoing support of the TVET system in Rwanda.

We extend our gratitude to the TQUM Project for its financial and technical support in the development of these training manuals.

We would also like to acknowledge the valuable contributions of all TVET trainers and industry practitioners in the development of this training manual.

The management of Rwanda TVET Board extends its appreciation to both its staff and the staff of the TQUM Project for their efforts in coordinating these activities.

This training manual was developed:

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Under Financial and Technical support of

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Financial and Technical support

KOICA through TQUM Project

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LIST OF ABBREVIATIONS and ACRONYMS

^{0}C: Celicius degree

A: Adenine

ADP: Adenosine Diphosphate

AGR: Agriculture

ANH: Animal Health

ASOs: Antisense Oligonucleotides

ATP: adenosine triphosphate

BaN_6: Barium azides

C: Cytosine

CBET: Competence Base Education and Training

COVID-19: Corona Virus Disease-2019

DNA: Deoxyribonucleic acid

e.g: Example

ELISAs: enzyme-linked immunosorbent assays

F1: First generation

F2: Second generation

Fe_2O_3: Iron(III) oxide

FOP: Food Processing

FOR: Forestry

G: Guanine

G: Guinine

GM: Genetically Modified

GMOs: Genetically Modified Organisms

H_2S: Hydrogen sulfide

HN3: Hydrozoic acid

I: Iodine

K: Potassium

LET: Leather Technology,

miRNA: MicroRNA

Mr: Mister

mRNA: Messenger RNA

N: Nitrogen

NADH: nicotinamide adenine dinucleotide

NADH: reduced Nicotinamide Adenine Dinucleotide

NaN3: Sodium nitride

$NH4^+$: Ammonium ion

O: Oxygen

-OH: Hydroxide ion

$Pb(N3)_2$: Lead (II) azide

PCR: Polymerase Chain Reaction

PH: **potential of hydrogen**

pH: potential of Hydrogen

PPE: Personal Protective Equipment

PPE: Personal Protective Equipment

RAB: Rwanda Agriculture and animal Resource Board

RNA: Ribonucleic acid

RNAi: RNA Interference

RQF: Rwanda Qualification Framework

RQF: Rwanda Qualification Framework

rRNA: Ribosomal RNA

RSB: Rwandan Standard Board

WIR: Water and Irrigation

WOT: Wood Technology

INTRODUCTION

This trainee's manual includes all the knowledge and skills required in food Networking and Internet Technologies specifically for the module of "**Applied Biology".** Trainees enrolled in this module will engage in practical activities designed to develop and enhance their competencies. The development of this training manual followed the Competency-Based Training and Assessment (CBT/A) approach, offering ample practical opportunities that mirror real-life situations.

The trainee's manual is organized into Learning Outcomes, which is broken down into indicative content that includes both theoretical and practical activities. It provides detailed information on the key competencies required for each learning outcome, along with the objectives to be achieved.

As a trainee, you will start by addressing questions related to the activities, which are designed to foster critical thinking and guide you towards practical applications in the labor market. The manual also provides essential information, including learning hours, required materials, and key tasks to complete throughout the learning process.

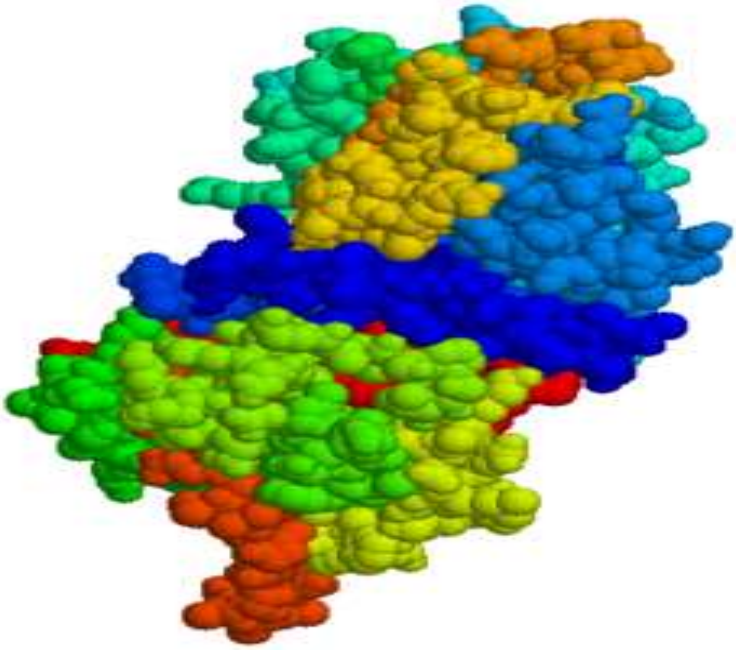
All activities included in this training manual are designed to facilitate both individual and group work. After completing the activities, you will conduct a formative assessment, referred to as the end learning outcome assessment. Ensure that you thoroughly review the key readings and the 'Points to Remember' section.

Module Units:

Unit 1: Describe biological macromolecule's structure and function

Unit 2: Illustrate patterns of genetic inheritance

Unit 3: Distinguish various microbial structures and their importance



Unit summary

This unit provides you with the knowledge, skills and attitudes required to describe biological macromolecule's structure and functions required to demonstrate knowledge of general biology. It covers the Carbohydrates, Lipids, Nucleic acids and Proteins.

Self-Assessment: Unit 1

Analyze the above illustration and answer the following questions:

What does the illustration show?

What do you think this unit is about based on the illustration?

Fill in and complete the self-assessment table below to assess your level of knowledge, skills and attitudes under this unit.

There is no right or wrong way to answer this assessment. It is for your own reference and self-reflection on the knowledge, skills and attitudes acquisition during the learning process.

Think about yourself: do you think you have the knowledge, skills or attitudes to do the task? How well?

Read the statements across the top. Put a check in a column that best represents your level of knowledge, skills and attitudes.

At the end of this unit, you will assess yourself again.

My experience **Knowledge, skills and attitudes**	**I don't have any experience doing this.**	**I know a little about this.**	**I have some experience doing this.**	**I have a lot of experience with this.**	**I am confident in my ability to do this.**
Classify types of carbohydrates					
Illustrate carbohydrates metabolism					
explain the use of carbohydrates based on their function					
classify of lipids based on their structure					
Identify food that are source of lipids					

My experience Knowledge, skills and attitudes	I don't have any experience doing this.	I know a little about this.	I have some experience doing this.	I have a lot of experience with this.	I am confident in my ability to do this.
Explain the use of lipids based on their function					
Distinguish types of nucleic acids					
Illustrate nucleotide					
Pay attention to agent that can cause DNA mutation					
Describe protein structures					
Draw protein structures					
Adequate use of protein based on their functions					

Key Competencies:

Knowledge	Skills	Attitudes
Classify carbohydrates	Illustrate carbohydrates metabolism	Use adequately carbohydrate based on its functions
Classify lipids	Select feed that are source of lipid	Use critically lipids based on their function
Identify types of nucleic acid	Illustrate structure of nucleotide	Pay attention on agents that cause DNA mutation

Knowledge	Skills	Attitudes
Describe types of protein structures	Draw various protein structures	Use critically proteins based on their function

Discovery activity:

Task 1: Read the below paragraph and answer related questions.

A healthy diet helps to protect against malnutrition in all its forms, as well as non-communicable diseases including diabetes, heart diseases, stroke, and cancer (WHO,29April2020). A balanced diet includes foods from the following five food groups: vegetables, fruits, grains, proteins and dairy. A balance diet gives your body the nutrients it needs to function correctly. To get the nutrition you need, most of your daily calories should come from fresh fruits, fresh vegetables, whole grains, legumes, nuts and learn proteins.

Among the above given food,

Which one contains carbohydrate?

Which one contains lipids?

Which one contains proteins?

How unbalanced diet can be a source of cancer?

What can you do to get most of the daily calories you need?

Topic 1.1: Explanation of Carbohydrates

Activity 1: Problem Solving

Task 2: Observe the below image of chemicals and answer the following questions:

Image1.

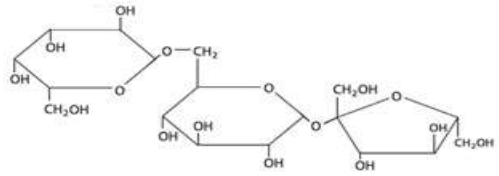


Image2.

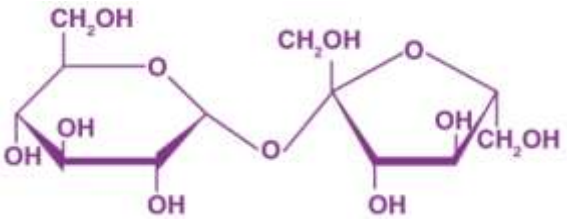


Image3.

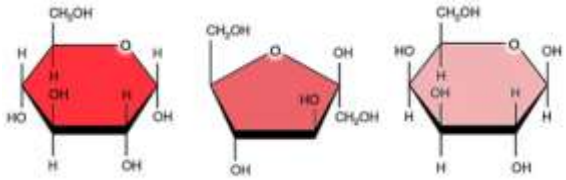
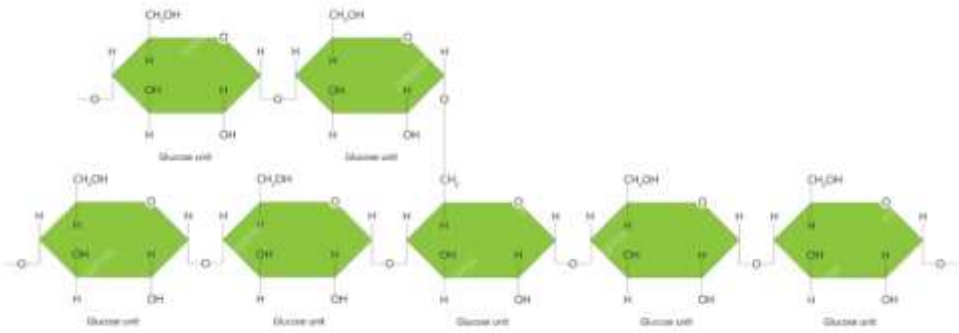


Image4.



Questions:

1. Which image indicating monosaccharide?

2. Which image indicating a disaccharide?

3. Which image indicating an oligosaccharide?

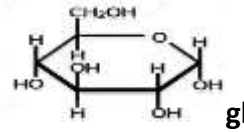
4. Which image indicating a polysaccharide?

Refer to the key facts 1.1 a for more clarifications on structural classification of carbohydrates

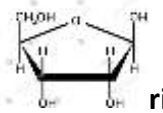
Key Facts 1.1a: Structural classification of carbohydrates

Carbohydrates are the **most abundant class of organic compounds found in living organisms.** They originate as products of photosynthesis, an endothermic reductive condensation of carbon dioxide requiring light energy and the pigment chlorophyll. Carbohydrates are divided into four classes: **monosaccharides, disaccharides, oligosaccharides, and polysaccharides**.

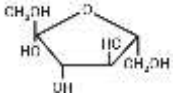
Monosaccharides: Also called simple sugars, are the simplest form of sugar and the most basic units of carbohydrates. The general formula is $C_nH_{2n}O_n$ or $(CH_2O)_n$ they are usually colorless, water soluble and crystalline solids. Some examples of monosaccharide are: glucose, ribose, galactose, fructose



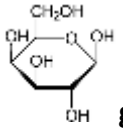
glucose ($C_6H_{12}O_6$)



ribose ($C_5H_{10}O_5$)

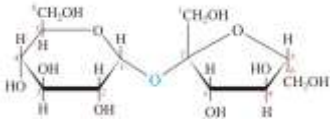


fructose ($C_6H_{12}O_6$)



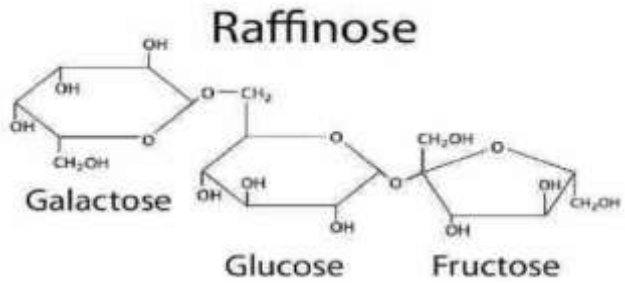
galactose ($C_6H_{12}O_6$)

Disaccharides: Also called double sugar, any substance that is composed of two molecules of simple sugars (monosaccharides) linked to each other. Disaccharides are crystalline water-soluble compounds. These are for example sucrose, maltose and lactose.

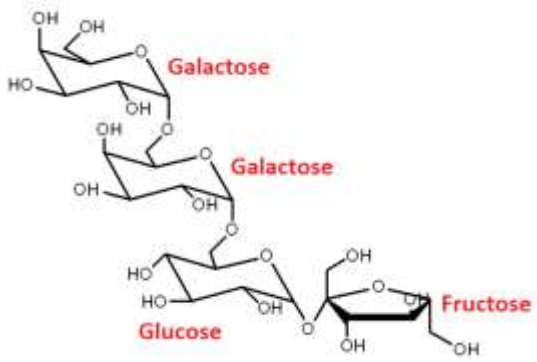


($C_{12}H_{22}O_{11}$)

Oligosaccharides: They are saccharide polymers containing a small number (typically three to ten) of monosaccharides (simple sugars). Oligosaccharides can have many functions including cell recognition and cell binding. Example of oligosaccharide is raffinose and stachyose.

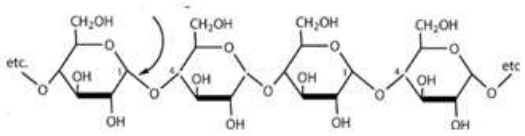


Stachyose



[1]

Polysaccharides: Polysaccharides or polycarbohydrates, are the most abundant carbohydrates found in food. They are long chain polymeric carbohydrates composed of monosaccharide units bound together by glucosidic linkages. This carbohydrate can react with water using amylase enzymes as catalyst, which produces constituent sugars. There are three common and principal types of polysaccharides such as cellulose, starch, and glycogen, all made by joining together molecules of glucose in different ways.



Carbohydrates are a major source of energy and can be found in a variety of foods. Here are several sources of carbohydrates:

Fruits: All fruits contain carbohydrates, but some have more than others. Fruits that are high in carbohydrates include bananas, grapes, mangoes, and melons.

Vegetables: Most vegetables contain some carbohydrates, but starchy vegetables like potatoes, corn, and peas are especially high in carbohydrates.

Dairy products: Milk and yogurt contain lactose, a type of sugar.

Legumes: Beans, lentils, and peas are all good sources of carbohydrates.

[1] https://en.wikipedia.org/wiki/Stachyose

Nuts and seeds: Nuts and seeds contain some carbohydrates, but they are also a good source of protein and healthy fats.

Grains: Bread, pasta, rice, and cereal are all made from grains, which are a good source of carbohydrates.

Activity 2: Guided Practice

Task 3: Read the below scenario and answer the following question:

Sophia is a college student preparing for her biology exam. She decides to track her diet for a day to understand how carbohydrates work in her body. Her breakfast includes whole-grain toast with peanut butter, a banana, and a glass of orange juice. For lunch, she has a bowl of brown rice with grilled vegetables. After a long day, she treats herself to a slice of chocolate cake for dessert after dinner.

Later, Sophia starts reflecting on how these foods are processed by her body and their role in maintaining her energy levels throughout the day. She comes up with several questions to deepen her understanding.

Questions:

1. a) Outline types of carbohydrates are present in Sophia's meals (simple or complex)?

b) Explain their differences.

2. Explain the way her body break down the carbohydrates in her breakfast (toast, banana, orange juice) into glucose.

Refer to the key facts 1.1 b for more clarifications on carbohydrates metabolism and function

Facts 1.1b:

Carbohydrates metabolism

Carbohydrate metabolism refers to the processes by which the body breaks down carbohydrates to generate energy, primarily in the form of glucose. These processes involve several biochemical pathways and are essential for maintaining blood sugar levels, energy production, and overall metabolic balance.

Key processes in carbohydrate metabolism:

Digestion and Absorption:

In the mouth: Salivary amylase begins the breakdown of complex carbohydrates (starch) into simpler sugars (maltose).

In the stomach and small intestine: Enzymes like pancreatic amylase further break down starches into disaccharides (e.g., maltose), and brush border enzymes (sucrase, lactase, etc.) break down disaccharides into monosaccharides (glucose, fructose, and galactose), which are absorbed into the bloodstream.

Glycolysis:

Occurs in the cytoplasm of the cell.

Glucose (6-carbon molecule) is broken down into two molecules of pyruvate (3-carbon molecules) through a series of enzyme-driven reactions.

This process produces a small amount of ATP (energy) and NADH (a carrier of electrons) and does not require oxygen (anaerobic).

Citric Acid Cycle (Krebs Cycle): If oxygen is available, pyruvate enters the mitochondria and is converted into acetyl-CoA, which then enters the citric acid cycle. This cycle produces more ATP, as well as NADH and FADH2, which are electron carriers.

Oxidative Phosphorylation: NADH and FADH2 donate their electrons to the electron transport chain in the mitochondria. This process, known as oxidative phosphorylation, generates the majority of ATP produced from glucose metabolism.

Glycogenesis: Excess glucose is stored in the liver and muscles as glycogen, a complex carbohydrate.

Glycogenolysis (Glycogen Breakdown):

When the body needs energy and blood glucose levels are low, glycogen is broken down into glucose through the process of **glycogenolysis**. This occurs primarily in the liver but also in muscles during exercise.

Gluconeogenesis: When carbohydrate intake is insufficient, the body can produce glucose from non-carbohydrate precursors like amino acids and glycerol through **gluconeogenesis**, primarily in the liver Carbohydrate metabolism is the body's process of breaking down carbohydrates (sugars and starches) for energy. It involves a series of complex chemical reactions that convert carbohydrates into glucose, the primary fuel source for cells.

Importance of carbohydrate metabolism:

Carbohydrate metabolism is essential for providing the body with energy, particularly for the brain and red blood cells, which rely primarily on glucose for fuel. It also plays a crucial role in maintaining blood glucose levels within a narrow range.

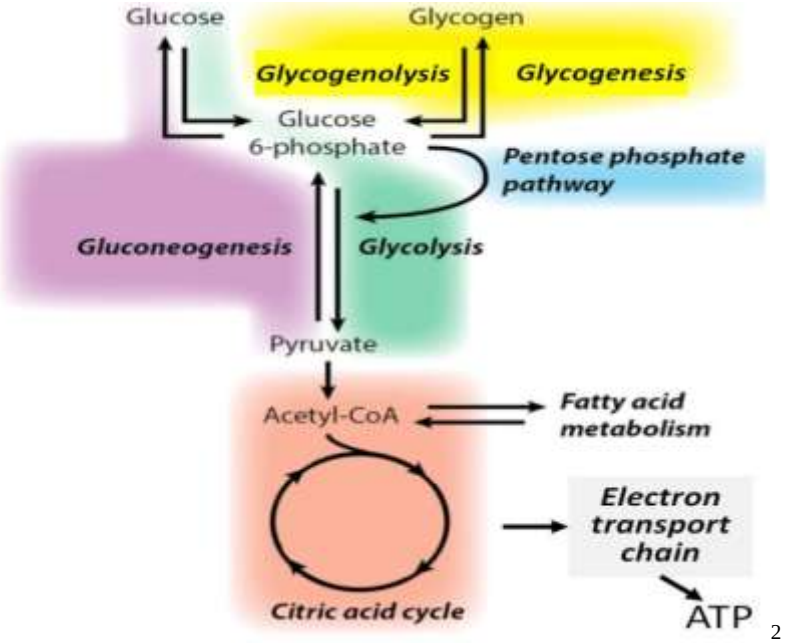
Regulation of Carbohydrate Metabolism:

Carbohydrate metabolism is tightly regulated by hormones:

Insulin: Released by the pancreas when blood glucose levels are high. It promotes the uptake of glucose by cells and stimulates glycogenesis.

Glucagon: Released when blood glucose levels are low, stimulating glycogen breakdown and gluconeogenesis.

Epinephrine and Cortisol: These stress hormones increase glucose availability by stimulating glycogen breakdown and gluconeogenesis.



[2]

Figure 1.Carbohydrate metabolisms

[2] Carbohydrate metabolisms

Figure 1. Block diagram of glucose metabolism. Each colored block represents a sequence of enzymatic reactions grouped together to simplify metabolism as major functional units.

Process Location ATP Produced Notes Glycolysis Cytoplasm 2 ATP (net) 4 ATP produced, 2 ATP consumed **Krebs Cycle** Mitochondria 2 ATP Per glucose molecule **Oxidative Phosphorylation** Mitochondria ~28-34 ATP Through electron transport chain **Total** ~30-38 ATP Per glucose molecule (aerobic conditions).

Table 1. ATP produced by carbohydrate metabolism

Stage	**Key Processes**	**ATP Produced**	**Notes**
Glycolysis	- Glucose → 2 Pyruvate - Substrate-level phosphorylation	**Net 2 ATP** (4 ATP generated, 2 ATP consumed)	Produces 2 NADH molecules (equivalent to ~5 ATP in oxidative phosphorylation)
Pyruvate Oxidation	Pyruvate	Acetyl-CoA	**0 ATP**
Citric Acid Cycle	Acetyl-CoA oxidation	**2 ATP** (GTP per glucose)	Produces 6 NADH (~15 ATP) and 2 FADH2 (~3 ATP) per glucose molecule
Oxidative Phosphorylation	Electron transport chain and chemiosmosis	**~28 ATP**	1 NADH → ~2.5 ATP; 1 FADH2 → ~1.5 ATP
Total ATP Production	**From complete oxidation of one glucose molecule**	**~32–34 ATP**	Efficiency depends on shuttle systems for NADH transport into mitochondria (e.g., malate-aspartate or

			glycerol-3-phosphate shuttle).

Functions of carbohydrates

1. Energy Source for the Body

Carbohydrates are primarily known for their role as a major energy source. When consumed, carbohydrates are broken down into glucose, which is utilized by the body's cells for energy. This is particularly important for high-energy-demand organs such as the brain and muscles. For instance, athletes often consume carbohydrate-rich foods before and after exercise to replenish glycogen stores and enhance performance.

2. Food Industry Applications

In the food industry, carbohydrates serve multiple functions:

Sweeteners: Sugars (simple carbohydrates) like sucrose, fructose, and glucose are widely used as sweeteners in various food products including candies, desserts, and beverages.

Thickeners and Stabilizers: Starches (complex carbohydrates) are used to thicken sauces and soups or to stabilize emulsions in dressings.

Preservatives: Certain carbohydrates can act as preservatives by inhibiting microbial growth due to their ability to bind water.

3. Health Benefits

Dietary fiber, a type of carbohydrate that is not easily digested by the body, has significant health benefits:

Digestive Health: Fiber aids in digestion by promoting regular bowel movements and preventing constipation.

Cholesterol Management: Soluble fiber can help lower blood cholesterol levels, reducing the risk of heart disease.

Blood Sugar Control: High-fiber foods can slow down the absorption of sugar, helping to manage blood sugar levels and reduce the risk of type 2 diabetes.

4. Industrial Uses

Beyond nutrition, carbohydrates have various industrial applications:

Bioplastics: Some types of polysaccharides are being researched for use in biodegradable plastics.

Pharmaceuticals: Carbohydrates are used in drug formulations as excipients or active ingredients due to their ability to improve solubility or stability.

Cosmetics: Carbohydrates like hyaluronic acid (derived from glucose) are commonly found in skincare products for their moisturizing properties.

5. Agricultural Applications

In agriculture, carbohydrates play a role in animal feed formulations. Grains such as corn and wheat provide energy-dense feeds for livestock. Additionally, certain carbohydrate sources are used in biofuels production; for example, starches from corn can be fermented to produce ethanol.

6. Cultural Significance

Carbohydrates also hold cultural significance across different societies through traditional foods that emphasize grains (like rice or bread), fruits, and legumes as staples in diets worldwide.

Activity 3: Application

Task 3: Answer the following question

In a small village where traditional agriculture thrives, the inhabitants primarily cultivate staple crops that are rich in polysaccharides, such as potatoes and corn. However, a recent pest invasion has devastated the crops, leading to a drastic reduction in polysaccharide intake among the villagers. As a result, many people begin to experience symptoms of energy depletion, digestive issues, and weakened immune responses. Without adequate polysaccharides to provide sustained energy and support gut health, the community faces a looming health crisis and a potential food shortage, leading to increased anxiety and social unrest.

As biologist help the people of that village:

Identify other possible sources of carbohydrates

Discuss about the role of carbohydrates in health benefit

Topic 1.2: Explanation lipids

 **Activity 1: Problem Solving**

 **Task 4: Read the following scenario and answer the below questions.**

Mutoni is sixteen years old. She is slim, tall and beautiful but she is not happy of size and sometime she is shy and complex when she is together with others. She wants to have a proportionally fatty size. Last week she went to nearest health center to ask for advice to the nutritionist about what to do to become fatty. The nutritionist told her that she must take fatty food that can help her to gain essential energy and cell health, but too much fat can increase calories above what the body needs and may lead to overweight. Additionally, the nutritionist advised her about food to like, to dislike and to limit in order to have a good size as follow:

Fat to love are from vegetables oils and fish oils.

Fat to limit are butter, cheese and heavy cream.

Fat to loose are trans fats, used in many processed foods such as donuts.

Questions:

What kind of biological macromolecule does contain fatty food?

Apart from having a proportionally fatty size, are there any other importance of fat in our body?

Even if fatty food I s important to our life, what is the discipline to be taken in front of fat?

Key Facts 1.2:

Structural classification of lipids

A lipid is any biological molecule that is soluble in nonpolar solvents (Chloroform, Diethyl ether, Benzene, Carbon tetrachloride).

The main types of lipids

Fatty Acids:

Saturated Fatty Acids: No double bonds between carbon atoms (e.g., palmitic acid).

Unsaturated Fatty Acids: One or more double bonds present (e.g., oleic acid, linoleic acid).

Triglycerides:

Composed of three fatty acids bound to a glycerol molecule. They serve as major energy storage molecules in animals and plants.

Phospholipids:

Composed of two fatty acids, a glycerol, and a phosphate group. They are key components of cell membranes, forming the lipid bilayer.

Sterols:

Complex lipids with a multi-ring structure (e.g., cholesterol). They are important for membrane structure and serve as precursors for steroid hormones.

Glycolipids:

Lipids with a carbohydrate attached. They play important roles in cell recognition and signaling, particularly in cell membranes.

Sphingolipids:

A class of lipids that includes sphingomyelin, which is important for forming the myelin sheath around nerve cells.

Waxes:

Long-chain fatty acids esterified to long-chain alcohols. Waxes provide protective coatings for plants and animals (e.g., beeswax, cutin).

Lipoproteins:

Complexes of lipids and proteins that transport lipids in the bloodstream (e.g., LDL and HDL cholesterol).

Lipids can be classified into several categories based on their chemical composition and structure. Here are the main classes:

Simple Lipids:

Fatty Acids: Carboxylic acids with long hydrocarbon chains. They can be saturated (no double bonds) or unsaturated (one or more double bonds).

Triglycerides (Triacylglycerols): Composed of glycerol and three fatty acids. They are the main form of stored energy in animals.

Compound Lipids

Compound Lipids: These lipids contain additional elements (such as phosphorus, nitrogen, or carbohydrates) along with fatty acids.

Phospholipids: Composed of glycerol, two fatty acids, and a phosphate group. They are major components of cell membranes.

Glycolipids: Composed of glycerol or sphingosine, one or more fatty acids, and carbohydrates. They also play a role in cell membranes and cellular recognition.

Lipoproteins: Complexes of lipids and proteins that transport lipids in the blood. They include HDL (high-density lipoprotein) and LDL (low-density lipoprotein).

Derived Lipids

Derived Lipids: These are compounds derived from simple and compound lipids.

Steroids: Lipids characterized by a carbon skeleton with four fused rings (e.g., cholesterol, hormones such as testosterone and estrogen).

Waxes: Esters of long-chain fatty acids with long-chain alcohols, which provide protective coatings (e.g., cutin on plant leaves).

Other Lipid Types:

Sphingolipids: Built on a sphingosine backbone, they include ceramides, sphingomyelin, and glycosphingolipids, essential for cell membranes and signaling.

Terpenes: Comprised of isoprene units; includes steroids and carotenoids, with roles in membrane structure and pigments.

Some major sources lipids are:

Animal Sources:

Meat: Beef, pork, lamb (contain varying amounts of saturated and unsaturated fats)

Poultry: Chicken, turkey (generally lower in saturated fat)

Dairy Products: Butter, cheese, whole milk (high in saturated fat)

Eggs: Contain both saturated and unsaturated fats

Fish: Fatty fish like salmon, tuna, and mackerel are rich in omega-3 fatty acids

Plant Sources:

Vegetable Oils: Olive oil, canola oil, sunflower oil, avocado oil (rich in unsaturated fats)

Nuts and Seeds: Almonds, walnuts, chia seeds, flaxseeds (good sources of unsaturated fats)

Avocados: High in monounsaturated fats

Some Fruits: Olives, coconut (contain some saturated fat)

Functions of lipids

1. Energy Storage and Supply

Lipids, particularly triglycerides, are a primary source of energy for the human body. They store more energy per gram than carbohydrates or proteins, making them an efficient form of energy reserve. When the body requires energy, it breaks down these stored lipids through a process called lipolysis, releasing fatty acids that can be used for fuel. This is especially important during prolonged periods of fasting or intense physical activity when immediate sources of energy (like glucose) are depleted.

2.Cell Membrane Structure

Lipids are fundamental components of cell membranes. Phospholipids, which have hydrophilic (water-attracting) heads and hydrophobic (water-repelling) tails, form bilayers that create the structural foundation of cellular membranes. This bilayer arrangement allows cells to maintain their integrity while controlling the movement of substances in and out of the cell. Cholesterol, another type of lipid, is interspersed within these membranes and contributes to membrane fluidity and stability.

3. Hormone Production

Steroids, a class of lipids that includes cholesterol, play crucial roles in hormone synthesis. Hormones such as estrogen, testosterone, cortisol, and adrenaline are derived from cholesterol and are vital for regulating various physiological processes including

metabolism, immune response, and reproductive functions. The production and regulation of these hormones are essential for maintaining homeostasis within the body.

4. Insulation and Protection

Lipids provide insulation to help regulate body temperature by forming a layer beneath the skin that reduces heat loss. Additionally, they protect vital organs by providing cushioning against mechanical shocks. This protective function is particularly important for organs like the kidneys and heart.

5.Nutrient Absorption

Dietary lipids facilitate the absorption of fat-soluble vitamins (A, D, E, K) in the intestines. These vitamins require lipids to be effectively absorbed into the bloodstream; without adequate dietary fats, deficiencies can occur despite sufficient intake of these vitamins.

6. Flavor and Texture in Food

In culinary applications, lipids contribute significantly to flavor and texture in food products. Fats enhance taste by carrying flavors and providing mouthfeel; they also influence cooking properties such as moisture retention in baked goods or creaminess in sauces.

7. Industrial Applications

Beyond biological functions, lipids have numerous industrial applications including their use as raw materials in cosmetics (e.g., creams containing oils), pharmaceuticals (e.g., lipid-based drug delivery systems), biodiesel production (using vegetable oils), and even as lubricants in machinery due to their viscosity properties.

Activity 2: Guided Practice

Task 5: Read the scenario below and answer the following questions:

Lily returns from the grocery store with fresh vegetables to make a salad for dinner. Recognizing the importance of a dressing, she decides to use olive oil, a healthy lipid known for its rich flavor and heart-healthy fatty acids. She combines olive oil with balsamic vinegar, salt, and black pepper to create the dressing. Understanding that the healthy fats in olive oil help absorb fat-soluble vitamins (A, D, E, and K) from the vegetables, she tosses the salad and prepares the table, eager to enjoy her nutritious meal. As biologist, explain the application of lipid in industrial.

Activity 3: Application

Task 6: Read the below scenario and answer the following question.

A 28-year-old woman named Sarah has recently adopted a strict low-fat diet in her pursuit of weight loss. Initially, she feels energized and motivated, but after a few weeks, she begins to experience fatigue, dry skin, and mood swings. During a visit to her healthcare provider, Sarah learns that her body is suffering from a deficiency of essential lipids, which are crucial for hormone production, absorption of fat-soluble vitamins, and maintaining healthy skin. Without adequate lipids in her diet, Sarah is at risk for inflammation and other metabolic issues, prompting her to reconsider her nutritional choices.

Questions

What food sources are rich in essential lipids that Sarah could incorporate back into her diet?

Topic 1.3: Explanation of nucleic acids

 Activity 1: Problem Solving

 **Task 7: Read the following scenario and answer the below questions.**

Ms. Johnson, a biology teacher, is explaining the importance of nucleic acids and their building blocks to her class. She introduces nucleic acids as the molecules that store and transmit genetic information. To help the students understand, Ms. Johnson explains the role of **nucleotides** in the structure and function of **DNA** and **RNA**.

Question

1. Enumerate the components of nucleotide.
2. Explain the structure of DNA.
3. Compare DNA and RNA.

Refer to the key facts 1.3 for more clarifications

Key Facts 1.3a: Structure of nucleotides and types of nucleic acid

A nucleotide is the fundamental building block of nucleic acids, such as DNA and RNA. Each nucleotide consists of three components:

1. Sugar:

In DNA, the sugar is deoxyribose, which has one less oxygen atom than ribose (the sugar in RNA).

In RNA, the sugar is ribose.

2. Phosphate group:

The phosphate group consists of a phosphorus atom bonded to four oxygen atoms (one of the oxygen atoms is hydroxy (-OH) or bonded to another nucleotide). This group gives nucleotides their acidic properties and is responsible for linking nucleotides together in a chain through phosphodiester bonds, forming the backbone of the nucleic acid.

3. Nitrogenous Base:

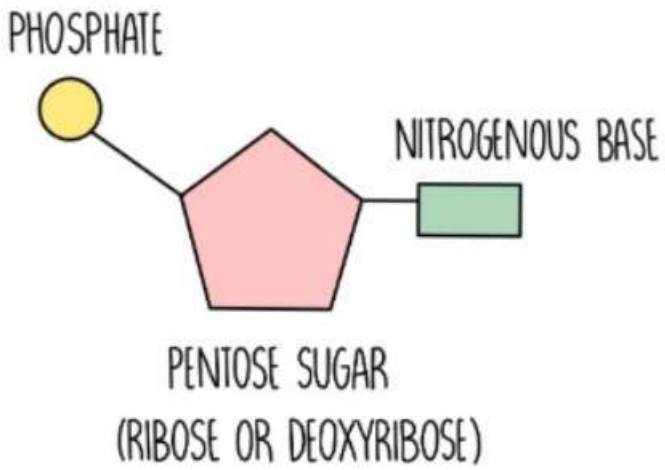
There are five primary nitrogenous bases divided into two categories:

Purines: Adenine (A) and Guanine (G), which have a double-ring structure.

Pyrimidines: Cytosine (C), Thymine (T) (found only in DNA), and Uracil (U) (found only in RNA), which have a single-ring structure.

General Structure of a Nucleotide

The general structure of a nucleotide can be represented as follows:



[3]

Visual Representation

1. Phosphate Group:

It is usually depicted as a circle or a "P" connected to four "O" atoms.

2. Sugar:

Deoxyribose and ribose are usually represented as a pentagon with hydroxy and hydrogen (or just hydrogen) at specific carbons.

Nitrogenous Base:

Purines (A and G) have a two-ring structure, while pyrimidines (C, T, and U) have a one-ring structure.

Connecting Nucleotides

[3] https://www.thesciencehive.co.uk/nucleotides-and-nucleic-acids#google_vignette

Nucleotides link together to form strands of DNA or RNA via phosphodiester bonds, where the phosphate group of one nucleotide binds to the hydroxyl group on the sugar of the next nucleotide, creating a sugar-phosphate backbone.

Nucleic acids

Nucleic acids are biopolymers essential for all known forms of life. They are macromolecules made up of nucleotide monomers, which consist of a sugar, a phosphate group, and a nitrogenous base. The two main types of nucleic acids are:

1. Deoxyribonucleic Acid (DNA):

Structure: DNA is typically double-stranded, forming a double helix. It consists of a sugar (deoxyribose), a phosphate group, and four nitrogenous bases (adenine [A], thymine [T], cytosine [C], and guanine [G]).

Function: DNA stores genetic information that is used in the development, functioning, and reproduction of all living organisms. It serves as a template for replication and expression of genes.

2. Ribonucleic Acid (RNA):

Structure: RNA is usually single-stranded and consists of a sugar (ribose), a phosphate group, and four nitrogenous bases (adenine [A], uracil [U], cytosine [C], and guanine [G]); note that uracil replaces thymine found in DNA).

Function: RNA plays several roles in the expression of genes, including messenger RNA (mRNA), which carries the genetic information from DNA to the ribosome for protein synthesis; transfer RNA (tRNA), which helps in the translation of mRNA into proteins; and ribosomal RNA (rRNA), which is a component of ribosomes.

A comparison between DNA (Deoxyribonucleic acid) and RNA (Ribonucleic acid):

Similarities:

Structure: Both DNA and RNA are nucleic acids, consisting of a sugar molecule, a phosphate group, and a nitrogenous base.

Function: Both store and transmit genetic information from one generation to the next.

Composition: Both consist of nucleotides, which are the building blocks of these molecules.

Synthesis: Both DNA and RNA are synthesized through a process of replication and transcription, involving enzymes like DNA polymerase and RNA polymerase.

Differences:

Sugar molecule:

DNA: Deoxyribose

RNA: Ribose

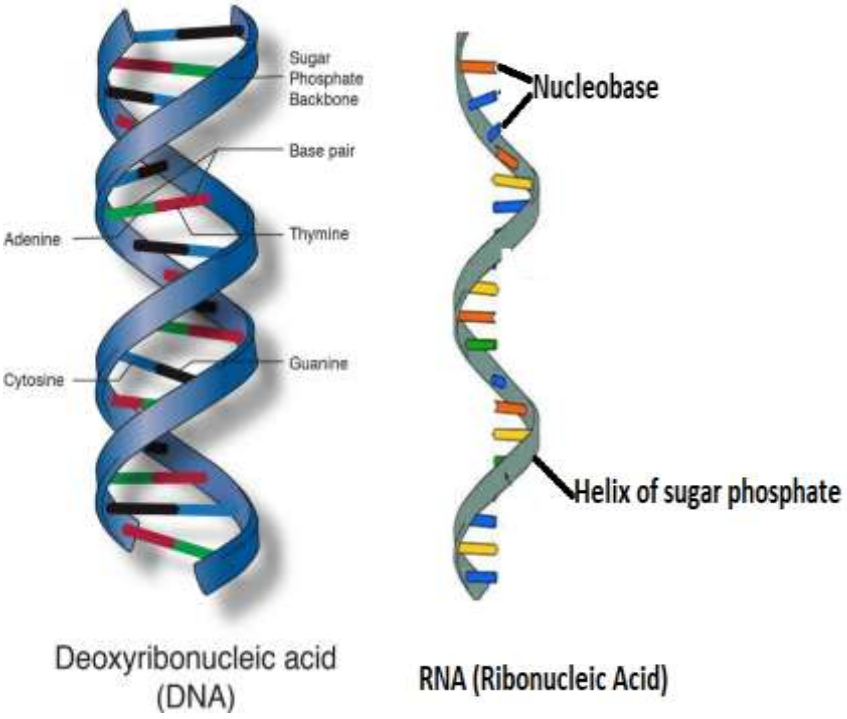
Nitrogenous bases:

DNA: Adenine (A), Thymine (T), Cytosine (C), and Guanine (G)

RNA: Adenine (A), Uracil (U), Cytosine (C), and Guanine (G) (Note: Uracil replaces Thymine in RNA)

Double vs. Single strand:

DNA: Typically double-stranded, forming a double helix RNA: Typically single-stranded.



Deoxyribonucleic acid (DNA)

RNA (Ribonucleic Acid)

Replication:

DNA: Replicates through a process of unwinding and re-synthesizing, with both strands serving as templates

RNA: Primarily synthesized through transcription, with RNA polymerase adding nucleotides to the growing strand

Stability:

DNA: Generally more stable and long-lasting

RNA: Less stable, with a higher tendency for degradation due to the presence of uracil and a single-stranded structure

Function in the cell:

DNA: Stores genetic information and serves as the blueprint for the cell's genetic makeup

RNA: Plays crucial roles in gene expression, including transcription, translation, and post-transcriptional regulation

Cellular location:

DNA: Present in the nucleus of eukaryotic cells, with some DNA also found in mitochondria and chloroplasts

RNA: Found throughout the cell, with different types of RNA having specific locations and functions

Key RNA types

- Messenger RNA (mRNA): Carries genetic information from DNA to the ribosomes.
- Transfer RNA (tRNA): Brings amino acids to the ribosome for protein synthesis.
- Ribosomal RNA (rRNA): Component of ribosomes, essential for protein synthesis.
- Small nuclear RNA (snRNA): Involved in the regulation of gene expression and processing of RNA.
- MicroRNA (miRNA): Regulates gene expression by binding to complementary mRNA.

Key DNA types

- Genomic DNA: Stores the entire genetic information of an organism
- Mitochondrial DNA: Codes for genes involved in the synthesis of ATP in mitochondria
- Plastid DNA: Codes for genes involved in photosynthesis and other processes in chloroplasts.

Activity 2: Guided Practice

Task 8: Read the scenario and answer the following questions:

You are a research scientist in a cutting-edge molecular biology lab, working on a project that investigates various types of nucleic acids, their structures, and functions. The lab is equipped with state-of-the-art equipment for gene sequencing, RNA analysis, and protein synthesis.

You are tasked with explaining the role of different nucleic acids to a group of biology students who are visiting the lab for the first time. As you walk them through the lab, you requested to:

a) Compare various nucleic acids, focusing on DNA and RNA.
b) Outline the functions of DNA and RNA.

Key Facts 1.3b:

DNA replication and its importance

Definition: Replication is the process by which a cell makes an exact copy of its DNA before cell division.

Process:

- **Initiation**: The process begins at specific locations in the DNA, called origins of replication. The double helix unwinds, and the two strands separate, creating a replication fork.
- **Elongation**: Enzymes called DNA polymerases add nucleotides to the growing new strand by pairing them with the complementary bases on the template strand (A with T and C with G). This occurs in the 5' to 3' direction.
- **Termination**: Once the entire DNA molecule has been copied, the process concludes. There are mechanisms that ensure fidelity, such as proofreading by DNA polymerase.

Importance: Replication ensures that each daughter cell receives an exact copy of the parent cell's genetic material, maintaining the integrity of genetic information across generations.

DNA Transcription

Definition: Transcription is the process of synthesizing RNA from a DNA template. This occurs in the nucleus of eukaryotic cells.

Process:

- Initiation: The enzyme RNA polymerase binds to the promoter region of a gene. This causes the DNA strands to unwind and separate.
- Elongation: RNA polymerase moves along the template strand, synthesizing a single strand of RNA by adding complementary RNA nucleotides (A with U and C with G).
- Termination: RNA synthesis continues until RNA polymerase reaches a termination signal in the DNA, at which point the enzyme detaches, and the newly synthesized RNA strand is released.

Types of RNA Produced:

- Messenger RNA (mRNA): Carries genetic information from DNA to ribosomes for protein synthesis.
- Transfer RNA (tRNA) and Ribosomal RNA (rRNA): Involved in protein synthesis and the assembly of ribosomes.

Importance: Transcription is critical for gene expression, as it produces the RNA molecules that are necessary for translation.

Applications of Nucleic Acids in Real Life

Nucleic acids, primarily DNA and RNA, play crucial roles in various fields due to their fundamental biological functions. Their applications span across medicine, biotechnology, agriculture, and forensic science.

1. Medical Applications

Nucleic acids are pivotal in the development of therapeutic agents and diagnostic tools:

Gene Therapy: Nucleic acids are used to treat genetic disorders by correcting defective genes responsible for disease development. Techniques such as CRISPR-Cas9 allow for precise editing of DNA sequences to repair mutations.

RNA Interference (RNAi): This technique utilizes small interfering RNAs (siRNAs) to silence specific genes associated with diseases such as cancer and viral infections. RNAi-based therapies are currently being developed and tested in clinical trials.

Antisense Oligonucleotides (ASOs): These are short strands of nucleic acids designed to bind to specific mRNA molecules, preventing them from producing harmful proteins. ASOs have shown promise in treating conditions like spinal muscular atrophy.

Diagnostics: Nucleic acids are essential in molecular diagnostics. Techniques like Polymerase Chain Reaction (PCR) enable the amplification of specific DNA sequences for detecting pathogens or genetic mutations. This is crucial for diagnosing infectious diseases and genetic disorders.

2. Biotechnology Applications

In biotechnology, nucleic acids facilitate various processes that enhance product development:

Recombinant DNA Technology: Scientists use nucleic acids to create genetically modified organisms (GMOs). For example, bacteria can be engineered to produce insulin or other therapeutic proteins by inserting human genes into their DNA.

Synthetic Biology: This field involves designing and constructing new biological parts using nucleic acids. Researchers can create custom organisms that perform specific tasks, such as biofuel production or environmental remediation.

Vaccine Development: Nucleic acid vaccines, which use mRNA or DNA to instruct cells to produce antigens that trigger an immune response, have been developed rapidly for diseases like COVID-19. These vaccines represent a novel approach that leverages the body's own cellular machinery.

Activity 3: Application

Task 9: Read the scenario and answer the following question.

A farmer in your location has a problem of why different varieties of maize have different performance on production. He/she is asking also why those varieties are having different resistance to pest and diseases. He/she knows that the maize plant arose from one common ancestor and all offsprings must have common genetic characteristics.

Question:

Base on the application of nucleic acid in biotechnology help that farmer to leave from that ambiguity.

Topic 1.4: Explanation of Proteins

Activity 1: Problem Solving

Task 10: Read the following scenario and answer the below questions.

Amina is a 20-year-old university student studying biology. Recently, she started feeling weak and lethargic, and her hair began to thin noticeably. After a visit to her doctor, she discovered that her diet consisted mainly of carbohydrates, with very little protein intake. The doctor explained that her symptoms could be linked to insufficient protein in her diet. She was advised to consume more protein-rich foods such as chicken, lentils, eggs, and dairy products to restore her energy levels and overall health.

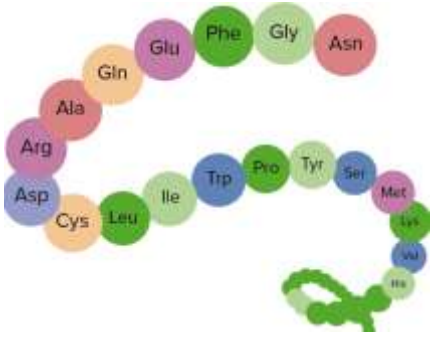
Question:

Explain the important of protein for Amina's body?

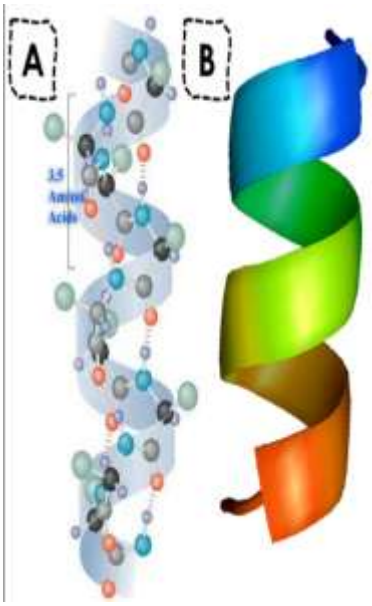
Key Facts 1.4a: Protein structure and function

The complete structure of protein can be described at four different levels of complexity: primary, secondary, tertiary, and quaternary structure.

Primary structure: Is defined as the linear amino acids sequence of protein's polypeptide chain.



Secondary structure: Is defined as the local spatial conformation of the polypeptide backbone excluding the side chains. It has a helicoidally shape.



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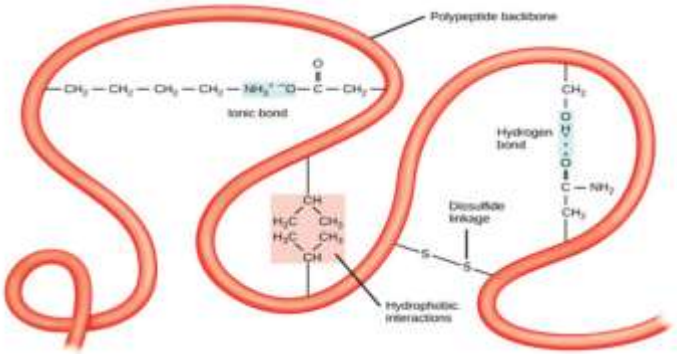
Tertiary structure: Refers to the three dimensional arrangement of all the atoms that constitute a protein molecule. It has twisted shape.

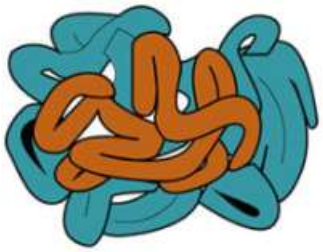


[5]

Quaternary structure: It consists of more than one polypeptide chain. It has a complex shape.

[4] https://byjus.com/
[5] Chemistry LibreTexts

Quaternary Structure



[6]

Major Sources of Protein

Proteins are essential for building and repairing tissues, producing enzymes and hormones, and supporting the immune system. Here are some major sources:

Animal Sources:

- **Meat:** Beef, pork, lamb, poultry (chicken, turkey)
- **Fish and Seafood:** Salmon, tuna, cod, shrimp, mussels
- **Eggs:** Excellent source of high-quality protein
- **Dairy Products:** Milk, cheese, yogurt (varying protein content)

Plant Sources:

- **Legumes:** Beans (black, kidney, chickpeas, lentils), peas
- **Nuts and Seeds:** Almonds, walnuts, peanuts, chia seeds, sunflower seeds, pumpkin seeds
- **Soy Products:** Tofu, tempeh, edamame
- **Grains:** Quinoa, brown rice, oats (contain some protein)
- **Vegetables:** Broccoli, spinach, asparagus (contain some protein)

[6] Chemistry LibreTexts

The functions of protein

Proteins play a crucial role in a wide array of applications in real life, spanning various fields such as medicine, food science, agriculture, and biotechnology. Here are some notable examples:

Medicine and Healthcare:

Therapeutic Proteins: Many drugs are recombinant proteins, such as insulin for diabetes management, monoclonal antibodies for cancer treatment (e.g., trastuzumab), and growth hormones.

Vaccines: Protein subunit vaccines use purified proteins from pathogens to elicit an immune response without causing disease, as seen in some COVID-19 vaccines.

Diagnostics: Proteins are used in diagnostic tests, such as enzyme-linked immunosorbent assays (ELISAs) for detecting diseases.

Food Industry:

Food Additives: Proteins serve as emulsifiers, stabilizers, and texturizers in various food products. For example, whey protein is used in protein shakes and bars.

Meat Alternatives: Plant-based proteins, such as soy and pea protein, are used to create meat analogs for vegetarian and vegan diets.

Agriculture:

Bioengineering: Proteins are utilized in genetically modified organisms (GMOs) to enhance certain traits, such as pest resistance in crops (e.g., Bt corn).

Animal Feed: Protein supplements, like fish meal or soybean meal, are important components in animal nutrition, promoting growth and health in livestock.

Biotechnology:

Enzymes in Industrial Processes: Proteins function as enzymes in various industrial applications, including detergents, food processing, and biofuels.

Synthetic Biology: Engineers design proteins for specific functions, such as metabolic pathways for producing biofuels or pharmaceuticals.

Research:

Molecular Biology Studies: Proteins are essential in research applications, including CRISPR technology for gene editing and studying cellular mechanisms.

Protein Engineering: Scientists modify proteins for novel functions or enhanced performance, such as producing more efficient enzymes for specific industrial applications.

Cosmetic Industry:

Skincare Products: Proteins such as collagen are used in anti-aging creams and treatments to improve skin elasticity and hydration.

Activity 2: Guided Practice

Task 11: Read the scenario and answer the following questions:

John is a professional athlete preparing for an upcoming marathon. During his routine check-up, his nutritionist emphasized the importance of proteins in his diet to ensure optimal performance and recovery. She explained that different types of proteins contribute to various bodily functions and recommended diverse protein sources, such as chicken, fish, beans, quinoa, and dairy products. She also explained how the structure of proteins relates

to their specific roles in the body, ensuring he understands why they are essential for both energy and recovery. As biologist,

a) Explain the structure of protein found in the feed recommended to John.

b) Outline the function of protein to John's body.

Key Facts 1.4b: Protein synthesis

Protein synthesis is the process in which cells make proteins. It occurs in two stages: **transcription** and **translation**.

Transcription

It is the transfer of genetic instructions in DNA to mRNA in the nucleus. It includes three steps: initiation, elongation, and termination. After the mRNA is processed, it carries the instructions to a ribosome in the cytoplasm.

Translation

It occurs at the ribosome, which consists of rRNA and proteins. In translation, the instructions in mRNA are read, and tRNA brings the correct sequence of amino acids to the ribosome. Then, rRNA helps bonds form between the amino acids, producing a polypeptide chain.

After a polypeptide chain is synthesized, it may undergo additional processing to form the finished protein.

Activity 4: Application

Task 12: Read the scenario and answer the following question

Maria, a 35-year-old athlete, has been experiencing fatigue and weakness over the past few weeks. She has been training for a marathon, but her energy levels have been dwindling, making it difficult for her to complete her runs. She has also been experiencing muscle cramps and joint pain, which are affecting her performance. Maria's doctor ordered some blood tests, which revealed that she has a protein deficiency. Specifically, her levels of albumin, globulin, and creatinine were lower than normal. The doctor explained that proteins are essential for building and repairing tissues, including muscles, bones, and skin. Without sufficient protein, Maria's body is unable to repair the damage caused by her intense training, leading to the symptoms she is experiencing.

As someone who studied protein help Maria in identification of source of protein in real life to overcome the protein deficiency in her body.

Formative Assessment

1. By using the below table of classes of carbohydrates, classify properly the following carbohydrates: Lignin, sucrose, lactose, fructose, raffinose, glucose, glycogen, maltose, sesames, galactose and starch.

Classes	Monosaccharide	Disaccharide	Oligosaccharide	Polysaccharide
Carbohydrate				

2. Answer by **true** or **false** at the end of statement by using **T** or F if the statement is **true** or **false** respectively.

a) Sucrose is a disaccharide composed by galactose and glucose.

b) Lactose is a disaccharide composed by glucose and galactose.

c) Maltose is a disaccharide composed by glucose and fructose.

3. Briefly distinguish the following carbohydrate metabolism: Glycolysis and Krebs cycle.

4.**Tick the true answer**.

One of the following groups of lipids is defined as esters of fatty acids and alcohol containing additional groups.

a) Simple lipids

b) Compound lipids

c)Derived lipids

5**.** Classify the following lipid into simple lipids, compound lipids and derived lipids: fatty acids, phospholipids, triglycerides, steroids, steryl esters, lipoproteins and vitamin A

6.The following are the functions of lipid except:

a) It is energy source

b) It works as intercellular messenger

c) It intervenes in growth and maintenance

d) It acts in shock absorption

e) Vitamins (A,E,D,K) are incorporated within it.

7.Based on nitrogen based and type of sugar, distinguish DNA from RNA as nucleic acid.

8. What do you understand by a "nucleotide"?

9. For the following DNA template propose a copy that will be made during DNA replication:

T…A…C…G... A…T…G…T…G…C…A…G

10. The following are the function of protein except:

a) Causes biochemical reaction

b) Maintains proper pH.

c) Bolsters immune health

d) Maintains diploid status of autosomal cells

e) Transports and stores nutrients

d) Provides energy

11. Discuss about the application of nucleic acids in the following domains:

Biotechnology

Medicine

What are the four main types of biological macromolecules?

Explain the primary functions of carbohydrates in living organisms.

Compare and contrast the structures of DNA and RNA. What are the key differences, and how do these differences affect their functions?

Evaluate the role of lipids in energy storage versus their structural roles in cell membranes. Which role do you think is more critical for cellular function, and why?

Base on the structure Outline four types of proteins.

Discuss the application of protein in the following domain:

a) Agriculture

b) Food industry

Points to Remember

Classes of carbohydrates based on their structure are: monosaccharides, disaccharides, oligosaccharides and polysaccharides.

Carbohydrate metabolisms are: glycolysis, Krebs or citric acid cycle and Electron transport chain.

Function of carbohydrates in our body are like providing energy and regulation of blood glucose, sparing the use of protein for energy, breaking down of fatty acids and prevent ketosis,etc

Classes of lipids based on their structure are: simple lipids, compound lipids, and derived lipids.

Functions of lipids in our body are: energy source, structuring cell membrane, acting as intercellular messengers, holding and carrying vitamins, and providing shock absorption.

Structure of nucleotides that consists of sugar molecule (ribose on RNA and deoxyribose on DNA) attached to a phosphate group and nitrogen base.

Main Types of nucleic acids are DNA and RNA.

DNA Replication is a process by which DNA makes a copy of itself during cell division. It helps to obtain two daughter cells that identical to mother cell.

Process of DNA transcription that is composed of three main step initiation, elongation and termination.

Types of proteins based on their level of complexity are: primary structure, secondary structure, tertiary structure and quaternary structure.

Function of proteins in our body are like growth and maintenance, acts in biochemical reactions, acts as messengers, providing structure, maintain pH, boosting immune system, transport and storing nutrients and providing energy.

Stages of how proteins are synthetized within our body are: transcription and translation.

Self-Reflection

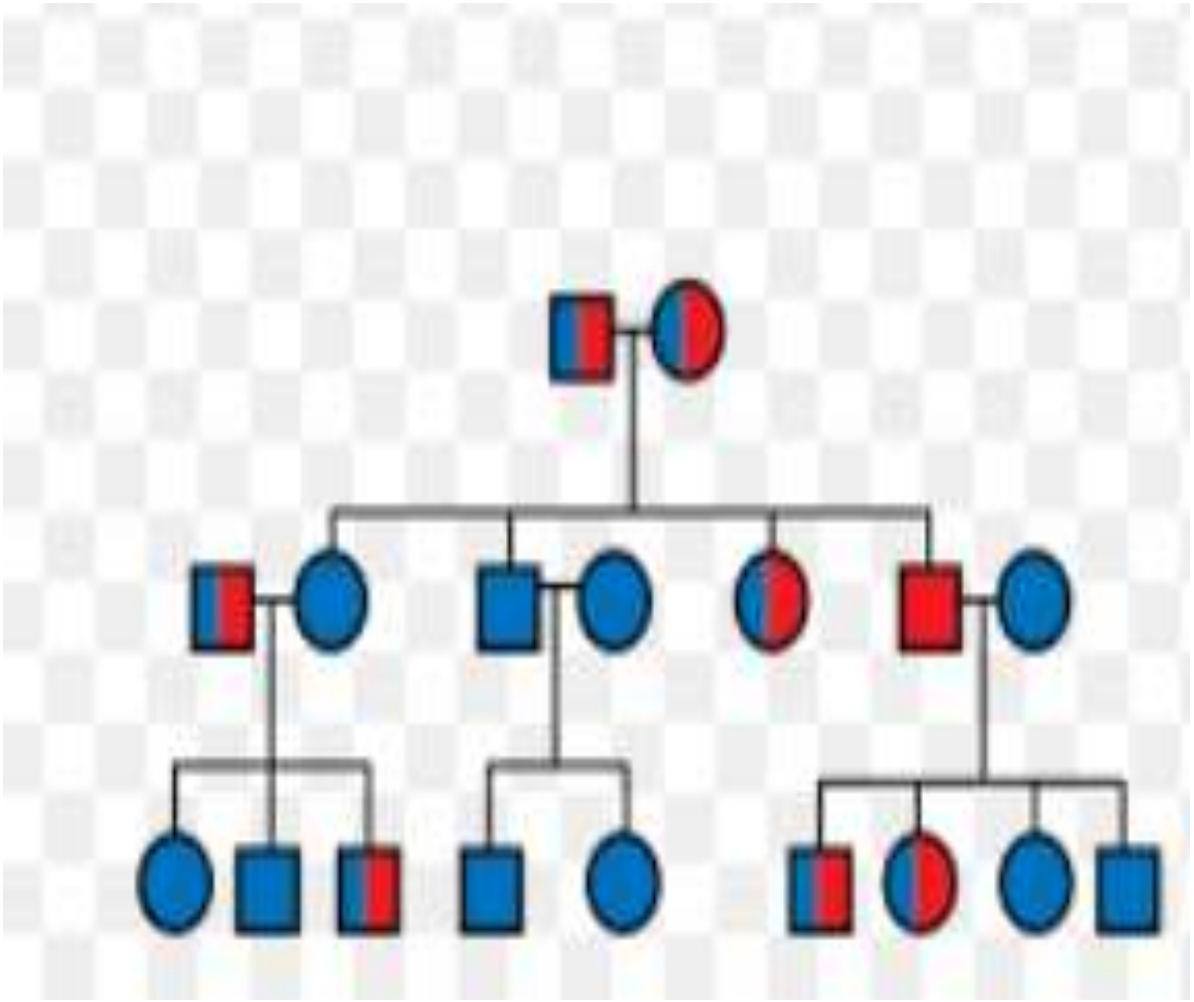
Read the statements across the top. Put a check in a column that best represents your level of knowledge, skills and attitudes.

My experience Knowledge, skills and attitudes	I don't have any experience doing this.	I know a little about this.	I have some experience doing this.	I have a lot of experience with this.	I am confident in my ability to do this.
Classify types of carbohydrates					
Illustrate carbohydrates metabolism					
Explain the use of carbohydrates based on their function					
classify of lipids based on their structure					
Identify food that are source of lipids					
Explain the use of lipids based on their function					

My experience Knowledge, skills and attitudes	I don't have any experience doing this.	I know a little about this.	I have some experience doing this.	I have a lot of experience with this.	I am confident in my ability to do this.
Distinguish types of nucleic acids					
Illustrate nucleotide					
Pay attention to agent that can cause DNA mutation					
Describe protein structures					
Draw protein structures					
Adequate use of protein based on their functions					

Fill in the table above and share results with the trainer for further guidance.

Areas of strength	Areas for improvement	Actions to be taken to improve
1. **2.** **3.**	**1.** **2.** **3.**	**1.** **2.** **3.**



Unit summary

This unit provides you with the knowledge, skills and attitudes required to Illustrate patterns of genetic inheritance required to demonstrate knowledge of general biology. It covers the genetic significance, genetic inheritance and genetic mutations.

Self-Assessment: Unit 2

1. Analyze the above illustration and answer the following questions:

a. What does the illustration show?

b. What do you think this unit is about based on the illustration?

2. Fill in and complete the self-assessment table below to assess your level of knowledge, skills and attitudes under this unit.

a. There is no right or wrong way to answer this assessment. It is for your own reference and self-reflection on the knowledge, skills and attitudes acquisition during the learning process.

b. Think about yourself: do you think you have the knowledge, skills or attitudes to do the task? How well?

c. Read the statements across the top. Put a check in a column that best represents your level of knowledge, skills and attitudes.

d. At the end of this unit, you will assess yourself again.

My experience **Knowledge, skills and attitudes**	**I don't have any experience doing this.**	**I know a little about this.**	**I have some experience doing this.**	**I have a lot of experience with this.**	**I am confident in my ability to do this.**
Define of genetics					
Compare genotype and phenotype					
Explain importance of genetics					
Discuss the concept of Genetic inheritance					

My experience Knowledge, skills and attitudes	I don't have any experience doing this.	I know a little about this.	I have some experience doing this.	I have a lot of experience with this.	I am confident in my ability to do this.
Explain the Mendel's laws and experience					
Discuss chromosomal theory					
Explain the concept of genetic mutation					
Enumerate causes of genetic mutation					
Distinguish types of genetic mutation					
Explain effects of genetic mutation					

Key Competencies:

Knowledge	Skills	Attitudes
Define genetics	Assess the genotype and phenotype	Avoid the factors which can cause unwanted genetic mutation
Differentiate genotype and phenotype	Use the Mendel's laws and experience	Avoid breeding that can read to consanguinity
List the importance of genetics	Apply concept Genetic inheritance	
State the concept Genetic inheritance	Analyze the genetic mutation	

Knowledge	Skills	Attitudes
Illustrate the Mendel's laws and experience	Examine the types of genetic mutation	
Explain Chromosomal theory		
State the concept of genetic mutation		
Identify the causes of genetic mutation		
Identify the types of genetic mutation		
Outline the effects of genetic mutation		

Discovery activity:

Task 12: Read and reflect on the following questions. Try to figure out what should be the answers.

Imagine you have a family with a history of blue eyes. However, you and your sibling have brown eyes. How can this be explained?

What traits do you think are most common in your family? Why do you think that is?

Have you ever wondered why some people have different eye colors or hair textures? What do you think causes these differences?

What do you think happens if two parents with different traits have a child? Can you think of any examples?

Do you know of any traits that run in your family? How far back can you trace them?

Topic 2.1: Explanation of Genetic significance

 **Activity 1: Problem Solving**

 **Task 13: Read the following scenario, and answer related questions**

Mr. Dalton is teaching a unit on genetics. He begins by defining genetics as the study of heredity and variation in organisms. He explains how genes, the units of heredity, are made up of DNA and are located on chromosomes.

"So, genetics is basically the blueprint for life," Mr. Dalton says. "It determines everything from your eye color to your height."

Alex raises his hand. "But Mr. Dalton, what about identical twins? They have the same genes, but sometimes they look a little different. Why is that?"

Mr. Dalton smiles. "That's a great question, Alex. It brings us to the concept of genotype and phenotype. Your genotype is your genetic makeup; all the genes you inherit from your parents. Your phenotype, on the other hand, is the physical expression of those genes. So, while identical twins have the same genotype, their phenotype can be influenced by environmental factors, like diet and lifestyle."

Riley, who has been quietly listening, interjects, "So, genetics is important, but it's not the only thing that determines who we are?"

"Exactly, Riley," Mr. Dalton replies. "Genetics plays a crucial role, but it's not the whole story. Environmental factors, like nutrition and exercise, can also have a significant impact on our development. That's why it's important to understand both nature and nurture."

Alex nods, thoughtful. "So, genetics can help us understand diseases and disorders, right?"

"Absolutely," Mr. Dalton says. "By studying genetics, scientists can identify genes associated with certain diseases and develop treatments. Genetics also plays a role in agriculture,

allowing us to breed crops with desirable traits, like resistance to pests and diseases. It's a fascinating field with endless possibilities."

As the class continues, Alex and Riley realize the importance of genetics in their everyday lives. They begin to appreciate the intricate interplay between genes and the environment, and how it shapes the world around them.

Basing on the above scenario:

a) How can you define genetics?
b) Differentiate genotype from phenotype.
c) What is the importance of genetics

Key Facts 2.1a: Genetic significance

Introduction to genetic

Genetic is the study of how living things receive common traits from previous generations. These traits are described by the genetic information carried by a molecule called DNA. The instructions for constructing and operating an organism are contained in the organism's DNA.

Etymology

Etymologically; genetic is the study of how genes and how traits are passed down from one generation to the next.

"Gen" means "beginning". Parents pass traits on to their children. Genetic is the science of genes and how traits are passed on from one generation to the next.

Genotype and phenotype

Genotype: A genotype is an individual's collection of genes. The expression of the genotype contributes to the individual's observable traits, called phenotype.

Phenotype: A phenotype is an individual's observable traits, such as height, eye color, and blood type. The genetic contribution to the phenotype is called genotype. Some traits are largely determined by the genotype, while other traits are largely determined by environmental factors.

History of Genetics

The origins of genetics lie in the development of theories of evolution. It was in 1858 that the origin of species and how species variability was developed after the research work of Charles Darwin and Wallace. They described how new species arose via evolution and how natural selection occurred to evolve new forms.

1866-Gregor Mendel discovers the basic principle of genetics. In 1866, unknown Augustinian was the first person to shed light on the way in which characteristics are passed down the

generations. Today, he is widely considered to be the father of genetics. Between 1856 and 1863 Mendel conducted experiments on peas plants, attempting to cross breed “true “lines in specific combinations. He identified seven characteristics: plant height, pod shape and colour, seed shape and colour, and flower position and colour. He found that when a yellow pea plant and a green pea plant were bred together their offspring was always yellow. However, in the next generation of plants, the green peas returned in a ratio3:1.

Importance of genetics

Genetics, the study of genes and heredity, has revolutionized various fields, including agriculture, animal health, and medicine. Here are some key applications:

Agriculture

Increasing Yield: Genetic engineering has led to the development of crops with higher yields, such as corn and soybeans, by manipulating genes related to growth and development.

Pest and Disease Resistance: Scientists have introduced genes from other organisms into crops to make them resistant to pests and diseases, reducing the need for pesticides.

Improving Nutritional Value: Genetic modification has been used to enhance the nutritional content of crops, such as increasing vitamin A in rice or iron in wheat.

Animal Breeding

Enhanced Productivity: Selective breeding based on genetic principles has led to the development of livestock with increased milk production, faster growth rates, and improved meat quality.

Disease Resistance: Genetic selection has been used to identify and breed animals with natural resistance to diseases, reducing the need for antibiotics and improving animal welfare.

Animal Health

Disease Diagnosis and Treatment: Genetic testing can identify animals with inherited diseases or predispositions to certain conditions, allowing for early intervention and improved management.

Gene Therapy: Experimental gene therapy techniques aim to correct genetic defects in animals, offering potential treatments for inherited disorders.

Medicine

Disease Diagnosis and Treatment: Genetic testing is used to diagnose inherited diseases, predict disease risk, and guide personalized treatment plans.

Gene Therapy: Gene therapy involves introducing genetic material into cells to treat diseases at their root cause, offering hope for conditions like cystic fibrosis and cancer.

Pharmacogenetics: This field studies how genetic variations affect drug response, allowing for personalized medicine and improved treatment outcomes.

Drug Development: Genetic engineering is used to produce recombinant proteins, such as insulin and growth hormone, for therapeutic use.

Activity 2: Guided Practice

Task 14: Read and answer the below question

Two cats are mated. One of the parent cats is long-haired (recessive allele). The litter which results contains two short-haired and three long-haired kittens. What does the second parent look like, and what is its genotype?

Activity 3: Application

Task 15: Read the below paragraph and answer the following question.

Genetic engineering in agriculture has revolutionized crop production, offering solutions to challenges like pests and climate change. For instance, scientists have developed genetically modified (GM) corn varieties resistant to the European corn borer, a destructive pest. This reduces the need for harmful pesticides, benefiting both farmers and the environment. However, concerns exist about potential risks to biodiversity and human health.

Question: How can genetic engineering be used to improve the nutritional value of staple crops like rice, addressing global malnutrition?

Topic 2.2: Explanation of Genetic inheritance

Activity 1: Problem Solving

Task 16: Read the following scenario and respond to related questions

Imagine a species of rose, *Rosa speciosa*, with two distinct traits:

Flower Color: Red (R) is dominant to white (r).

Thorns: Presence of thorns (T) is dominant to thornless (t).

We have two purebred rose bushes:

Bush 1: Red flowers and thorns (RRTT)

Bush 2: White flowers and thornless (rrtt)

These two bushes are crossed. Predict the genotype and phenotype ratios

Key Facts 2.2.a: Genetic inheritance

Concept of genetic inheritance

Inheritance: It is a mechanism in which one class (generation) acquires the properties of another class (generation). There are four types of inheritance:

- Dominant
- Recessive
- Codominant
- Intermediate

Inheritance is also the transmission of traits or information from one generation of individuals or cells to the next.

Monohybrid: It is a cross between parents differing in only one trait or in which only one trait is being considered. Example is the case when colour is being inherited

Dihybrid: Is a cross between parents in which two pairs of contrasting characters are studied simultaneously for the inheritance pattern. Example is the case when colour and shape are being inherited.

Mendel's Laws and experiments

Mendel's Laws

Law of dominance: Mendel’s law of dominance in simple words states that **recessive traits are always dominated or masked by dominant trait**.

Law of segregation: Mendel’ law of segregation states that a diploid organism passes a randomly selected allele for a trait to its offspring, such that the offspring receives one allele form each parent.

Law of independent assortment: Pairs of alleles for each characteristic or gene segregate independently of each other. Independent assortment allows the calculation of genotypic and phenotypic ratios based on the probability of individual gene combinations.

Mendel experiment

Mendel performed seven types of monohybrid crosses, each involving contrasting traits for different characteristics. Out of these crosses, all of the F1 offspring had the phenotype of one parent, and the F2 offspring had a 3:1 phenotypic ratio. On the basis of these results, Mendel postulated that each parent in the monohybrid cross contributed one of two paired unit factors to each offspring, and every possible combination of unit factors was equally likely.

Punnett Squares in monohybrid Crosses

Punnett squares are a valuable tool in genetics, helping us visualize and predict the possible outcomes of genetic crosses. They are particularly effective for illustrating monohybrid crosses, which involve a single gene with two different alleles.

Key Outcomes:

Genotypic Ratio: The Punnett square reveals the expected ratio of different genotypes (genetic makeup) among the offspring. For example, in a simple monohybrid cross between two heterozygous individuals (Aa x Aa), the genotypic ratio is typically 1 AA : 2 Aa : 1 aa.

Phenotypic Ratio: Based on the genotypes and the dominance relationships between the alleles, the Punnett square predicts the expected ratio of different phenotypes (observable traits) in the offspring. In the same monohybrid cross example, if "A" is dominant, the phenotypic ratio would be 3 dominant phenotype : 1 recessive phenotype.

The Punnett square is a simple diagram that shows the different possible combinations. Here is an example for the offspring of two organisms with the same Aa allele combination:

	A	A
A	AA	Aa
A	Aa	Aa

Example: In pea plants, yellow seeds are dominant and green seeds are recessive. Cross two heterozygous individuals (Yy).

	Y	Y
Y	YY	Yy
Y	Yy	Yy

Punnett Squares in Dihybrid Crosses

A dihybrid cross involves tracking the inheritance of two different genes simultaneously. This results in a larger Punnett square with 16 possible outcomes.

Example: Pea Plant Traits

Let's consider a classic example: crossing pea plants that are heterozygous for two traits:

Seed Shape: Round (R) is dominant to wrinkled (r)

Seed Color: Yellow (Y) is dominant to green (y)

The genotypes of the parent plants would be RrYy.

Setting Up the Punnett Square:

Determine possible gametes: Each parent can produce four different gametes due to independent assortment: RY, Ry, rY, and ry.

Create the grid: A 4x4 grid is needed to accommodate all possible combinations.

Fill in the grid: Combine the gametes from each parent to fill in the 16 boxes with the possible genotypes of the offspring.

Key Outcomes:

Genotypic Ratio: The genotypic ratio in a dihybrid cross of two heterozygous individuals is typically 1 RRYY : 2 RRYy : 1 RRyy : 2 RrYY : 4 RrYy : 2 Rryy : 1 rrYY : 2 rrYy : 1 rryy.

Phenotypic Ratio: The phenotypic ratio in a dihybrid cross of two heterozygous individuals for two independently assorting traits is typically 9:3:3:1. This means that:

9 offspring will exhibit both dominant traits (e.g., round and yellow seeds).

3 offspring will exhibit one dominant and one recessive trait (e.g., round and green seeds).

3 offspring will exhibit the other dominant and recessive trait (e.g., wrinkled and yellow seeds).

1 offspring will exhibit both recessive traits (e.g., wrinkled and green seeds).

Key Points:

Dihybrid crosses demonstrate the law of independent assortment, which states that the inheritance of one gene does not influence the inheritance of another gene.

Example Dihybrid Cross: Pea Plants

Let's consider the following traits in pea plants:

Trait 1: Seed shape (Round = R, Wrinkled = r)

Trait 2: Seed color (Yellow = Y, Green = y)

Parental Genotypes

Let's cross two pea plants that are heterozygous for both traits.

Parent 1: RrYy (Round Yellow)

Parent 2: RrYy (Round Yellow)

Gametes Production

Each parent can produce four types of gametes based on the combinations of alleles:

Possible gametes from Parent 1: RY, Ry, rY, ry

Possible gametes from Parent 2: RY, Ry, rY, ry

Creating the Punnett Square

Now, we can set up a 4x4 Punnett square:

	RY	Ry	rY	Ry
RY	RRYY	RRYy	RrYY	RrYy
Ry	RRyY	RRyy	RryY	Rryy
rY	rRYY	rRYy	rrYY	rrYy
ry	rRyY	rRyy	rryY	rryy 1

Analyzing the Results

From the completed Punnett square, we can see the following genotypes for the offspring, which we can count to find the phenotypic ratios:

Genotypes:

RRY Y: 3

RRY y: 1

RrY Y: 6

RrY y: 2

RRyy: 1

Rryy: 2

rrY Y: 1

rrY y: 1

rryy: 1

Phenotypes:

Round Yellow (RRYY): 9 (RRY Y + RRY y + RrY Y + RrY y)

Round Green (RRyy): 3 (RRyy + Rryy)

Wrinkled Yellow (rrYY): 3 (rrY Y + rrY y)

Wrinkled Green (rryy): 1 (rryy)

Phenotypic Ratio

From the counts of phenotypes, we see that the ratio is:

9 Round Yellow : 3 Round Green : 3 Wrinkled Yellow : 1 Wrinkled Green

Activity 2: Guided Practice

Task 17: Reflect on the following questions and provide answers

In pea plants, tallness (T) is dominant over shortness (t). If a tall plant (Tt) is crossed with a short plant (tt), what are the possible genotypes and phenotypes of the offspring?

For more clarification, refer to the key fact 2.2.b. You may ask more explanations to your teacher where necessary.

Key Facts 2.2.b: Chromosomal Theory

Location of Genes:

Core Idea: Genes are located on specific positions (loci) on chromosomes. This theory, developed by Theodor Boveri and Walter Sutton, connected Mendel's laws of inheritance with the behavior of chromosomes during cell division.

Homologous Chromosomes:

Definition: Homologous chromosomes are pairs of chromosomes, one inherited from each parent. They carry genes for the same traits but may have different versions (alleles) of those genes.

Meiosis: The Process of Gamete Formation

Key Points:

Meiosis is a specialized type of cell division that reduces the chromosome number by half, producing haploid gametes (sperm and egg cells).

It involves two rounds of division: Meiosis I and Meiosis II.

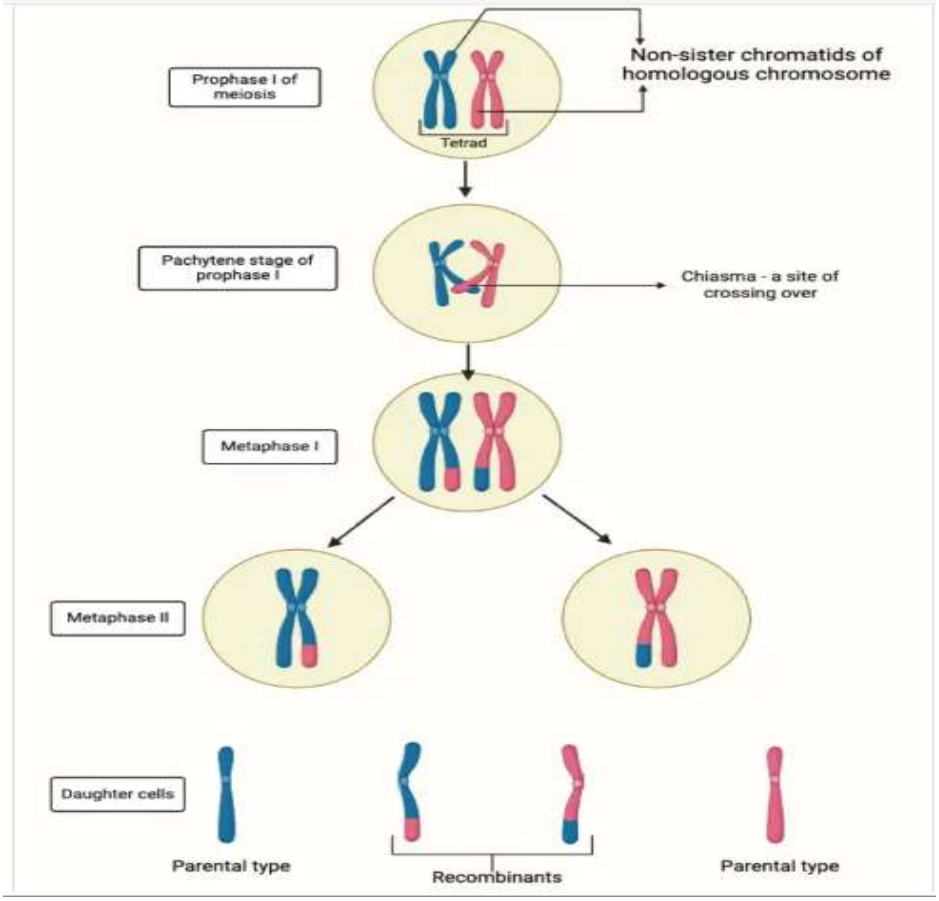
During Meiosis I, homologous chromosomes pair up and exchange genetic material (crossing over), leading to genetic diversity.

Meiosis II separates sister chromatids, resulting in four haploid daughter cells.

Gamete Formation: The End Result of Meiosis

Outcome: Meiosis produces haploid gametes (sperm and egg cells) with a unique combination of chromosomes and genes.

Significance: When two gametes (one from each parent) fuse during fertilization, the diploid zygote is formed, inheriting genetic material from both parents.



The Chromosomal Theory of Inheritance has numerous real-life applications across various fields:

1. Genetic Counseling and Diagnosis:

Identifying Genetic Disorders: By understanding how genes are inherited on chromosomes, genetic counselors can assess the risk of individuals inheriting genetic disorders. This information helps families make informed decisions about family planning.

Prenatal and Newborn Screening: Chromosomal analysis, such as karyotyping, can detect chromosomal abnormalities in fetuses or newborns, leading to early intervention and management.

2. Agriculture and Animal Breeding:

Selective Breeding: Breeders use their knowledge of chromosomal inheritance to select and breed organisms with desirable traits, such as increased crop yield or disease resistance in livestock.

Genetic Modification: Understanding chromosome structure and gene location is crucial for developing genetically modified organisms (GMOs) with improved traits.

3. Forensic Science:

DNA Fingerprinting: Chromosomal analysis is used in DNA fingerprinting to identify individuals based on their unique genetic profiles, aiding in criminal investigations and paternity testing.

4. Evolutionary Biology:

Understanding Evolutionary Relationships: By studying chromosomal changes over time, scientists can reconstruct evolutionary relationships between different species.

5. Personalized Medicine:

Pharmacogenetics: Understanding how genetic variations on chromosomes affect drug response allows for personalized medicine, tailoring treatments to individual patients.

Activity 3: Application

Task 18: Read the scenario and answer the following question.

Scenario: A farmer in your village has a problem of low yield of pea plant due to use of local seed, fertilizer, pesticide and apply all crop maintenance practices but still the problem remains. As biologist help that farmer to perform dihybrid cross between two pea plants. One plant is heterozygous for both traits (TtYy) and the other is homozygous recessive for both traits (ttyy), where:

T = tall stems, t = short stems

Y = yellow seeds, y = green seeds

Task: Set up a Punnett square for this dihybrid cross.

Questions:

a) List the possible gametes from each parent.

b) Determine the genotypic and phenotypic ratios of the offspring.

Topic 2.3: Introduction to Genetic mutations

Activity 1: Problem Solving

Task 19: Read the following scenario and answer related questions.

In Kabuga, a small village located at Musha Sector, Rwamagana District, there is an orchard famous for its delicious red apples. The orchard owner, Mr. SIBOMANA, has been growing these apples for over 20 years. One day, while inspecting the trees, Mr. SIBOMANA discovers a single apple on one of the branches that is bright green instead of red. Curious about this unusual apple, he decides to investigate further.

While recalling last season, Mr. SIBOMANA remembered he had accidentally mixed some seeds from a neighboring orchard that produces green apples. He wonders if this green apple is a result of a genetic change. Determined to learn more, he decides to conduct an experiment.

Mr. SIBOMANA decides to take seeds from the green apple and plant them alongside seeds from his red apples. He wonders if the green apple will produce more green apples or if the traditional red apples will dominate.

What do you think caused the green apple to appear on Mr. Smith's tree?

For more clarification, refer to the key fact 2.3.a

Key Facts 2.3.a : Genetic mutations

Concept of genetic mutations

Gene mutation

It is a change in the DNA sequence that makes up a gene. This change can affect a single nucleotide, pair or larger segments of a chromosome

In this case, chromosome fragments can be **deleted**, **duplicated**, **inverted**, **translocated** to **various chromosomes**, or otherwise **rearranged**, resulting in changes such as modification

of the gene dosage, the complete absence of genes, or gene sequence alterations.

Mutations can result from DNA copying mistakes made during cell division, exposure to ionizing radiation, exposure to chemicals called mutagens, or infection by viruses.

Germ line mutations occur in the eggs and sperm and can be passed on to offspring, while somatic mutations occur in body cells are not passed on.

Causes of genetic mutations

Spontaneous causes

Mutations may be spontaneous in nature. It is the net result of all that can go wrong with DNA during the life cycle of an organism. It is a mutation occurring in the absence of mutagens, usually due to errors in the normal functioning of cellular enzymes.

Physical mutagens

Example of physical agents causing mutation are ultraviolet (UV) and gamma radiation. Radiation exerts its mutagenic effect either directly or by creating free radicals that in turn have mutagenic effects.

Chemical mutagens

Chemical mutagens are alkylating agents and azides. Alkylating agents are compounds that work by adding an alkyl group to the guanine base of the DNA molecule, preventing the strand of the double helix from linking as they should. This causes breakage of DNA strands, affecting the ability of the cancer cell multiply.

Azides: Any of a class of chemical compounds containing three nitrogen atoms a group. Examples of Azides: Hydrozoic acid HN_3; Sodium nitride NaN_3, Barium azides BaN_6; Lead (II) azide $Pb(N_3)_2$.

Activity 2: Guided Practice

Task 20: Refer to the above scenario (task19) and answer the following questions:

1. If the green apple's color is due to a genetic mutation, what do you think a mutation is? Can you think of any other examples of mutations you might have heard of?

2. If Mr. SIBOMANA plants the seeds from the green apple, what might happen when they grow? Will they all be green, or could there be a mix of red and green apples? Why?

3.How might the presence of green apples affect Mr. SIBOMANA's orchard? Would customers prefer the red apples, or could the green apples attract attention?

Key Facts 2.3.b. :

Types of genetic mutations

Thera are two main types of genetic mutation such as **gene mutation** and **chromosomal mutation.**

Gene mutation: There are 4 types of gene mutations:

Point mutations: Change a single nucleotide.

Frameshift mutations: Are additions or deletions of nucleotide that cause a shift in the leading frame.

Base substitution mutation: It is the simplest type of gene-level mutation, and it involves the swamping of one nucleotide for another during DNA replication. For example, during replication, a thymine nucleotide might be inserted in place of a guanine nucleotide

Chromosome mutations

Structural mutation: 5 main type of structural mutation are **chromosomal aberrations deletion**, **duplication**, **inversion**, and **translocation**.

Deletion occurs when a portion of chromosome is deleted, or taken out, which can make that chromosome less functional.

Chromosomal aberration or **abnormalities**: Are change to the structure or number of chromosomes which are the strands of condensed genetic material.

Duplication: Is a type of mutation that involves the reproduction of one or more copies of gene or a region of chromosomes.

Inversion: Occurs when a chromosome breaks in two places; the resulting piece of DNA is reversed and inserted into the chromosome. Genetic material may or not be lost as a result of the chromosome breaks.

Translocation: It occurs when a piece of one chromosome breaks off and attaches to another chromosome. This can lead to mental retardation, infertility and cancer.

Numerical mutation (polyploidy, aneuploidy)

It is a mutation which alter the chromosome structure, size or gene arrangement. It includes **polyploidy** and **aneuploidy**.

Polyploidy: The condition in which a normal diploid cell or organism acquires one or more additional sets of chromosomes. In other words, the polyploidy cell or organism has three or more times the haploid chromosome number.

Aneuploidy: having missing or extra chromosomes is a condition called aneuploidy. The risk of having a child with an aneuploidy. Increases as a woman ages. Trisomy is the most common aneuploidy. The different conditions of aneuploidy are: Nullisomy (2n-2), monosomy (2n-1), Trisomy (2n+1) and tetrasomy (2n+2).

Effects of genetic mutations

There are harmful effects, beneficial effects and neutral effects.

Harmful effects of genetic mutations

Harmful mutation may cause disorders or cancer. A genetic disorder is a disease caused by a mutation in one or a few genes.

Beneficial effects of genetic mutations

They lead to new versions of proteins that help organisms adapt to changes in their environment.

Neutral effects of genetic mutations

The majority of mutation have neither negative nor positive effects on the organism which they occur. These mutations are called neutral mutations. Examples include silent point mutations. They are neutral because they do not change the amino acids in the proteins they encode.

Activity 3: Application

Task 21: Read the following scenario and answer related questions.

In a war-torn country, Sarah, a pregnant woman, faces the grim realities of her situation as she struggles to find food and clean water in her devastated village. Exposed to toxic

pollutants resulting from the conflict, her unborn child may experience genetic mutations that can lead to serious birth defects or disorders. As her due date approaches, Sarah grapples with a complex mix of hope and fear about her child's future, anticipating potential health challenges brought on by the harsh environment. With medical care limited, she confronts the unsettling possibility of a lifetime of struggle for both herself and her vulnerable child amidst the ongoing chaos.

As student who finish to studied biology, explain to Sarah the causes of genetic mutations that can lead to serious birth defects or disorders.

Formative Assessment

1. Etymologically, define the term “genetic”

2. Define the following terms: a) Mutation

b) Mutagen

3. Differentiate phenotype from genotype.

4. Answer by **True** or **False** by using **T** or **F** respectively at the end of statement explaining the causes of genetic mutation

a) Spontaneous cause is the net result of all that can go wrong with DNA during the life cycle of an organism.

b) Physical causes are azides and alkylating agents that are found in the nature.

c) Chemical causes are chemicals like U.V light and gamma radiations emitted by minerals

5. Kamana is a breeder in RAB he has consider the color of seed of beans during breeding activity while her colleague Akimana has considered both size and color of soya beans during her breeding activity.

a) Whose one has carried out dihybrid ?
b) Whose one has carried out monohybrid?

6. A breeder cross two Indian pigs with different colors of the fur. A female was white (WW) while the male was brown fur (ww). At F1 it was found that all individuals were white fur. If 2 individuals (male and female) of F1 were isolated for mating, what will be the ratios of genotype and phenotype at F2?

7. A breeder breeds two (2) varieties of maize each with two different characteristics or alleles colour and size. Female was white colour (WW) and tall (TT) while the male was yellow (ww) and short (tt). At F1 all individuals gave seeds with white colour (Ww) and the size of maize

plants were tall (Tt). Give the genotypes and phenotype ratios of F2 if the alleles were WT, Wt, Wt, and wt.

8. Choose the correct answer: Some type of chromosomal mutation are the following, except:

a) Chromosomal aberrations
b) Deletion
c) Duplication
d) Base substitution mutation
e) Polyploidy

9. Sometimes genetic mutation may have benefit to living organism. **Yes** or **Not**

If YES, justify your answer, if NOT, justify your answer.

10. Given the following varieties of mutations, classify them accordingly in gene mutation or chromosomal mutation:

a) Point mutations
b) Inversion
c) Polyploidy
d) Chromosomal aberration
e) Frameshift mutations
f) Duplication

11. In what ways can genetic research contribute to advancements in personalized medicine?

12. Describe a real-world example where genetic has been applied in agriculture. What are the benefits and potential risks?

13. If a homozygous dominant plant (RR) is crossed with a homozygous recessive plant (rr), what will be the genotype and phenotype ratios of the F1 generation?

14. If two F1 plants from the above cross are crossed, what will be the genotype and phenotype ratios of the F2 generation?

15. Two pea plants, one homozygous dominant for round yellow seeds (RRYY) and the other homozygous recessive for wrinkled green seeds (rryy), are crossed. What are the possible genotypes and phenotypes of the F1 generation?

16. If two F1 plants from the above cross are crossed, what are the expected phenotypic ratios in the F2 generation?

Points to Remember

Gene Location: Genes are located on specific positions (loci) on chromosomes.

Homologous Pairs: Organisms inherit two sets of chromosomes, one from each parent, forming homologous pairs.

Segregation: During meiosis, homologous chromosomes separate, ensuring each gamete receives only one copy of each chromosome and its associated genes (Mendel's Law of Segregation).

Independent Assortment: The separation of different pairs of homologous chromosomes during meiosis is independent of one another (Mendel's Law of Independent Assortment).

Linkage: Genes located on the same chromosome tend to be inherited together.

Crossing Over: Homologous chromosomes can exchange segments of DNA during meiosis, leading to genetic recombination.

Gamete Formation: Meiosis produces haploid gametes (sperm and egg cells) with a unique combination of chromosomes and genes.

Gene mutation: It is a change in the DNA sequence that makes up a gene.

Mutations can result from DNA copying mistakes made during cell division, exposure to ionizing radiation, exposure to chemicals called mutagens, or infection by viruses.

Germ line mutations occur in the eggs and sperm and can be passed on to offspring, while somatic mutations occur in body cells are not passed on.

Causes of genetic mutations are:

Spontaneous causes: It is the net result of all that can go wrong with DNA during the life cycle of an organism. It is caused by due to errors in the normal functioning of cellular enzymes.

Physical mutagens: Physical agents causing mutation are ultraviolet (UV) and gamma radiation.

Chemical mutagens: Chemical mutagens are alkylating agents and azides.

Types of genetic mutations are:

Gene mutation: There are 4 types of gene mutations:

Point mutations

Frameshift mutations

Base substitution mutation

Chromosome mutations

Structural mutation: 5 main type of structural mutation are chromosomal aberrations deletion, duplication, inversion, and translocation.

Numerical mutation (polyploidy, aneuploidy)

Effects of genetic mutations

Harmful effects of genetic mutations: It may cause disorders or cancer

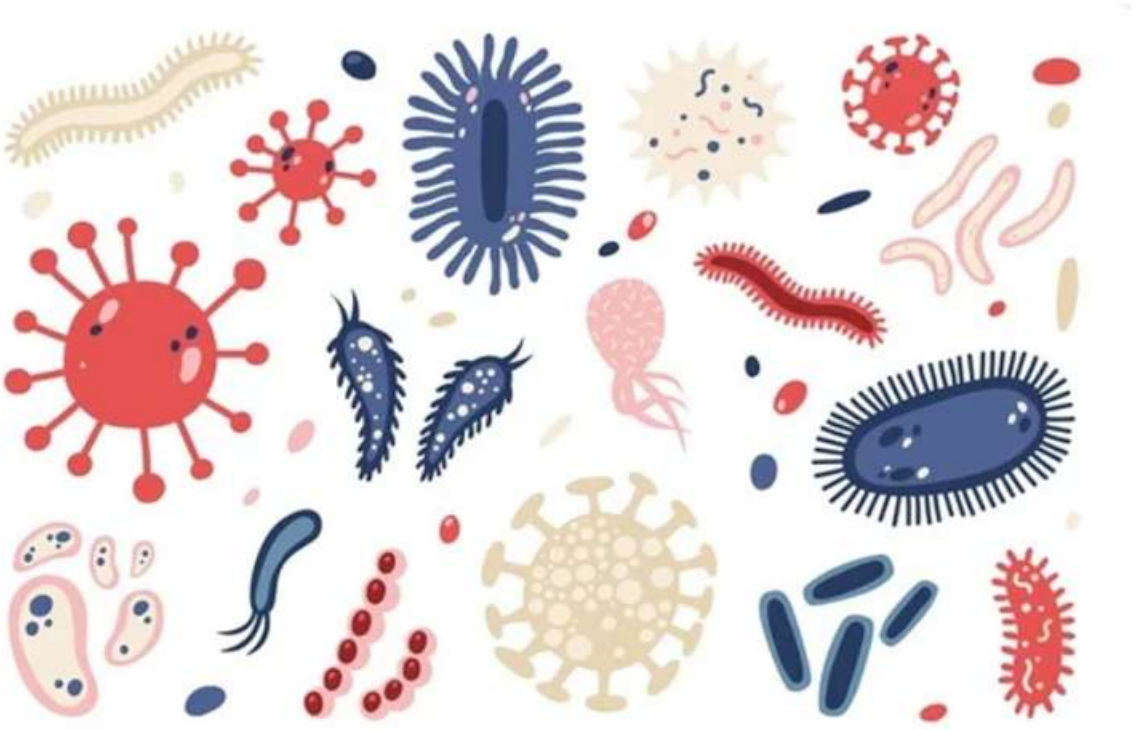
Beneficial effects of genetic mutations that help organisms adapt to changes in their environment.

Neutral effects of genetic mutations that do not have neither negative nor positive effects on the organism which they occur.

Self-Reflection

My experience Knowledge, skills and attitudes	I don't have any experience doing this.	I know a little about this.	I have some experience doing this.	I have a lot of experience with this.	I am confident in my ability to do this.
Define of genetics					
Compare genotype and phenotype					
Explain importance of genetics					
Discuss the concept of Genetic inheritance					
Explain the Mendel's laws and experience					
Discuss chromosomal theory					
Explain the concept of genetic mutation					
Enumerate causes of genetic mutation					
Distinguish types of genetic mutation					
Explain effects of genetic mutation					

UNIT 3: DISTINGUISH VARIOUS MICROBIAL STRUCTURES AND THEIR IMPORTANCE



Unit summary

This unit provides you with the knowledge, skills and attitudes required to distinguish various microbial structures and their importance required to demonstrate knowledge of general biology It covers the Microbiology, Characteristics of microbes and Microbial growth.

Self-Assessment: Unit 3

1. Analyze the illustration above and answer the following questions:

a) What does illustration show?

b) Based on illustration, what do you think this unity is about?

2. Fill and complete the self-assessment table below to assess your level of knowledge, skills and attitudes under this unit.

a) Think about yourself: do you think you have the knowledge, skills or attitudes to do the task? How well?

b) Read the statements across the top. Put a tick (V) in a column that best represents your level of knowledge, skills and attitudes.

My experience Knowledge, skills and attitudes	I don't have any experience doing this.	I know a little about this.	I have some experience doing this.	I have a lot of experience with this.	I am confident in my ability to do this.
Remember history of microbiology					
Outline importance of microbes					

My experience Knowledge, skills and attitudes	I don't have any experience doing this.	I know a little about this.	I have some experience doing this.	I have a lot of experience with this.	I am confident in my ability to do this.
Describe characteristics of bacteria					
Describe characteristics of virus					
Describe characteristics of algae					
Describe characteristics of fungi					
Describe characteristics of protozoa					
Identify growth requirements of microbes					
Illustrate growth phase of microbes					
Carry out culturing and observation of microbe in the laboratory					

Key Competencies:

Knowledge	Skills	Attitudes
Remember history of microbiology	Using microbes in our daily activities based on their importance	Apply sanitation behavior in front of microbes prevention
Outline types of microbes	Distinguish microbes based on their characteristics	Respect microbes prevention measures
Show growth of microbes	Provide growth requirement during microbes culturing laboratory	Be careful during microbe observation to prevent contamination

Discovery activity:

Task 22: Read the below scenario and answer the related questions:

Ntwari is a farmer who has a project of increasing production from his farm. It is in the rainy season. Last month, he harvested maize and directly stored them without letting them to dry well. After few days the bad smell came out from the store. The same smell was the same as that came out of the silage pit due to bad silage making. Last week, he visited his maize field and he remarked abnormalities of yellow lines on some maize leaves. Leaving from maize field he visited the potatoes field. Arrived there, he remarked some wilted plants without being damaged by pests. The same day he visited his cattle farm. At arrival, the workers told him that one of his cow is showing the symptoms of high fever and enlarged lymph nodes. When he returned home, he carried out a report by summarizing the situations of his crops and his dairy cattle. He took a decision to go to ask advice to the experts in crop production and animal production about how he could solve the problems found in his farms in order to find an adequate solution.

Questions:

a) What kind of pathogen that causes stored maize to produce bad smell?

b) What does indicate yellow lines on maize leaves?

c) What kind of pathogen that causes potato plants to wilt?

d) What kind of microbe that causes that dairy cattle to show the symptoms of high fever and enlarged lymph nodes?

Topic 3.1: Introduction to Microbiology

 **Activity 1: Problem Solving**

 **Task 23: Read the scenario and answer the following questions.**

In a small community, several residents begin experiencing severe stomach cramps, diarrhea, fever, and vomiting. The local health clinic receives numerous cases within a few days. Dr. Maria, a microbiologist, is called in to investigate the source of this mysterious outbreak. As a biologist:

a) Identify the possible sources of the infection to that community

b) Outline the importance of microbes in ecosystem.

Key Facts 3.1: History and importance of microbes

Microbiology is study of microorganisms, or microbes, a diverse group of generally minute simple life-forms that include bacteria, archaea, algae, fungi, protozoa, and viruses.

Microbiology essentially began with the development of the microscope. Although others may have seen microbes before him, it was Antonie Van Leeuwenhoek, a Dutch draper whose hobby was lens grinding and making microscopes, who was the first to provide proper documentation of his observations. His descriptions and drawings included protozoans from the guts of animals and bacteria from teeth scrapings. His records were excellent because he produced magnifying lenses of exceptional quality. Leeuwenhoek conveyed his findings in a series of letters to the British Royal Society during the mid-1670s. Although his observations stimulated much interest, no one made a serious attempt either to repeat or to extend them. Leeuwenhoek's "animalcules," as he called them, thus remained mere oddities of nature to the scientists of his day, and enthusiasm for the study of microbes grew slowly. It was only later, during the 18th-century revival of a long-standing controversy about whether life could develop out of non-living material, that the significance of microorganisms in the scheme of nature and in the health and welfare of humans became evident.

Contribution to microbiology

Microbiology came into being largely through studies of bacteria. The experiments of Louis Pasteur in France, Robert Koch in Germany, and others in the late 1800s established the importance of microbes to humans.

Louis Pasteur

The studies on fermentation led Pasteur to take interest to work in microbiology. His contributions to microbiology are as follows:

In 1864 he disproved the theory of spontaneous generation of disease and postulated the germ theory of disease: he stated that disease cannot be caused by air or vapor but it is produced by the microorganisms present in air.

Robert Koch

He was the German bacteriologist who discovered the bacteria that causes Anthrax, septicaemia, tuberculosis and cholera, and his methods enabled others to identify many more important pathogens. Thanks to his contributions to the field, he is sometimes known as the father of bacteriology, a title shared with Louis Pasteur.

Importance of microbes

Microbes play essential roles in ecosystems, with key functions including:

1. Decomposition: They recycle nutrients by breaking down dead organic matter, enriching soil fertility and structure.

2. Biogeochemical Cycling: Microbes are crucial in the carbon, nitrogen, and phosphorus cycles, facilitating nutrient transformation and availability for plants.

3. Bioremediation: Microbes help reduce pollution by degrading harmful substances like heavy metals and hydrocarbons, and they can enhance plant capabilities to detoxify contaminants.

4. Symbiosis with Plants: They form beneficial relationships, such as mycorrhizal associations that improve nutrient and water uptake, and nitrogen-fixing partnerships that enhance soil fertility.

5. Pathogen Control: Beneficial microbes can suppress plant diseases, promoting crop health and reducing the need for chemical pesticides.

6. Fermentation and Production: Microbes are vital for producing food items (like yogurt and bread) and biofuels (such as ethanol).

7. Health and Disease: In humans, gut microbes assist with digestion, metabolism, and immune defense, protecting against harmful pathogens.

8. Soil Structure Improvement: Microbial activity aids in soil aggregation, enhancing aeration and water retention while producing enzymes that facilitate nutrient access.

Application of microbes in real life

In agricultural industry

Microbiology enables farmers drive yield and productivity in a sustainable way. Deriving solution from various naturally occurring microorganisms such as bacteria and fungi can protect crops from pests and diseases and enhance plant productivity and fertility.

In health and medicine industry

Medical microbiologist provides services to aid the diagnosis and management of infectious diseases and help ensure the safety of those at risk of acquiring infectious diseases, both in hospitals and the community.

In maintenance of the environment

The most significant effect of the microbes on earth is their ability to recycle the primary elements that make up all living systems, especially carbon, oxygen, and nitrogen. This is achieved by decomposition of dead living organism that may be harmful to the environment.

Thus along with all these benefits, microbes greatly contribute in maintaining sustainability of environment.

In pharmaceutic and biotechnology industry

The most important contribution of microbiology to pharmaceutical industry is the development of antibiotics. Apart from drugs and bio products development, microbiology contributes towards quality control of pharmaceutical laboratory.

Harmfulness of microbes

- Micro-organisms, especially moulds, can trigger respiratory infections and allergies if they grow in our workplaces or homes.
- Microscopic growth can also lead to fungal staining of carpets and algal growth on paint, which can be difficult and costly to remove.
- Bacteria and fungi are common causes of malodour in home textiles, clothing, and footwear.
- Bacteria and other microbes are frequent contaminants of food and water, which can lead to food poisoning and serious illness.
- Microbes are the agents of food spoilage and decomposition of clothing and sheltering materials.
- They cause disease in animals and plants.
- Microbes such as bacteria, viruses, fungi, and protozoans, can cause disease in humans.
- ***Salmonella typhi*** is a pathogenic bacteria that causes typhoid fever.
- Rhinoviruses cause the common cold in humans.
- Plasmodium is a tiny protozoan that causes malaria.
- They are the ones that cause food to deteriorate.

Activity 2: Guided Practice

Task 24: Individually, answer the following question.

In a small village, citizens observe that after heavy rainfall, the nearby river's water has turned cloudy and emits a foul odor. They suspect that microorganisms are responsible for the decline in water quality. As biologist, help the citizens to:

a) Identify the causes of water to turn cloudy and emits a foul odor.
b) Identify agricultural runoff rich in nutrients that entered the river to cause the undesirable changes in the water.

Activity 3: Application

Task 25: Answer the below question

The population lives in the zone of industrial city facing severe soil contamination from heavy metals like cadmium and lead.

As biologist, help the population to:

a) Explain the roles of microbes in pollution reduction
b) Explain the roles of microbes in agriculture

Topic 3.2: Characterization of microbes

Activity 1: Problem Solving

Task 26: Read the scenario and answer the below questions

Maria, a high school student, decided to create a science project about the different types of microbes and their impact on humans, animals, and plants. She collected samples from various sources: the soil in her garden, the yogurt in her fridge, and the mold growing on a slice of bread. She also read about microbes that cause diseases in humans and animals. Her teacher asked her to identify the types of microbes in her samples and explain their roles in different ecosystems. Outline the types of microbes collected by Maria.

Key Facts 3.2. Microbes

a) Bacteria

There are some characteristics of bacteria:

- Lack of membrane-bound organelles.
- Unicellular
- Small (usually microscopic) size
- Presence of various shape such as bacillus (rod). Coccus (sphere), spirilla (spiral) and vibrio (curved)
- They have a cell wall that is made of peptidoglycans, a polymer of sugar and amino acids
- They reproduce by binary fission
- They may have flagella or pili for movement and interaction with the environment
- They can survive in extreme conditions and some can cause diseases

Few examples of the many ways in which bacteria are applied in real life

- **Food Production:** Bacteria are used in the production of yogurt, cheese, sauerkraut, and other fermented foods.

- **Biotechnology:** Bacteria are used in biotechnology to produce a wide range of products, including insulin, antibiotics, and enzymes.
- **Bioremediation:** Bacteria can be used to clean up oil spills, degrade pollutants, and treat wastewater.

Virus

- They are infectious particles that reproduce by using a host cell's machinery.
- They are made up of genetic material (RNA or DNA) and a protein coating (capsid).
- Some have an envelope around the capsid.
- They are non-cellular, metabolically inert, and obligate intracellular parasites.
- They have spikes that help them attach to the host cell.
- They are very diverse and microscopic, ranging from 0.02-0.3 µm in size.

Few examples of the many ways in which virus are applied in real life

- **Gene Therapy:** Viruses can be modified to deliver therapeutic genes to target cells, offering potential treatments for genetic disorders and cancer.
- **Vaccines:** Viruses can be used to create vaccines by either using a weakened or inactivated form of the virus to trigger an immune response, or by using viral vectors to deliver genetic material that stimulates the immune system.

c) Fungi

- Fungi are eukaryotic, non-vascular, non-motile and heterotrophic organisms.
- They may be unicellular or filamentous.
- They reproduce by means of spores.
- Fungi exhibit the phenomenon of alteration of generation.
- Fungi lack chlorophyll and hence cannot perform photosynthesis.
- Fungi store their food in form of starch.
- Biosynthesis of chitin occurs in fungi.
- The nuclei of fungi are very small.
- The fungi have embryonic stage. They develop from the spore.

- The mode of reproduction is sexual and asexual.
- Some fungi are parasitic and can infect the host.
- Fungi reproduce a chemical called pheromone which leads to sexual reproduction in fungi.

Few examples of the many ways in which fungi are applied in real life

- **Food Production:** Fungi are used in the production of various foods, such as bread, cheese, and mushrooms.
- **Antibiotics:** Penicillin, one of the first antibiotics, was discovered from a type of fungus, and many other antibiotics are derived from fungi.
- **Bioremediation:** Fungi can be used to degrade pollutants and clean up contaminated.

d) Algae

- They are eukaryotic organisms with a discrete nucleus and chloroplasts
- They are photosynthetic and have chlorophyll and other pigments
- They have no roots, stems, or leaves and lack a well-defined body
- They are either unicellular or multicellular and are mostly free-living
- They are found in moist places, especially in water
- They reproduce by spore formation or by the physical contact of haploid gametes.

Few examples of the many ways in which algae are applied in real life

- **Biofuel Production:** Algae can be used to produce biofuels, such as biodiesel and bioethanol, as a renewable energy source.
- **Food and Supplements:** Algae are used as a source of food and dietary supplements, such as spirulina and chlorella.
- **Oxygen Production:** Algae play a crucial role in photosynthesis, contributing significantly to the production of oxygen in the atmosphere.

Protozoa

- Protozoans are single-celled organisms.
- They are either free-living or parasites.
- They lack a cell wall.
- They are generally heterotrophic.
- They divide by binary fission, schizogony, or budding.
- Examples of protozoa are Amoeba, Euglena, Paramecium and Leishmania

Few examples of the many ways in which protozoa are applied in real life

- **Environmental Indicators:** Certain protozoa are used as indicators of water quality, as their presence or absence can signal pollution levels.
- **Research:** Protozoa are used in research to study cell biology and other fundamental biological processes.

Activity 2: Guided Practice

Task 27: Read the scenario and answer the following questions.

A family falls ill after consuming a fruit salad made with unwashed strawberry that were tainted with harmful microbes due to careless in food preparation.

a) Identify the category of microorganism which cause the food contamination

b) Discuss the characteristics of that category of microorganism.

Activity 3: Application

Task 28: Read the scenario and answer the below question:

In a small town, an outbreak of measles prompted local health officials to organize a vaccination campaign in order to protect the community. They decided to use a modified live virus vaccine, which contains a weakened form of the measles virus. This approach is designed

to stimulate the immune system to produce antibodies against the virus without causing the disease itself. As the day of the vaccination clinic approached, a group of concerned parents gathered to learn more about the vaccine's safety and efficacy. As biologist explain how does the modified live virus vaccine work.

Topic 3.3: Explanation of Microbial growth

Activity 1: Problem Solving

Task 29: Read the scenario and answer the below questions

A team of microbiologists is studying the growth of a newly discovered bacterial species isolated from a deep-sea hydrothermal vent. This bacterium, named "Pyrococcus profundus," thrives in extremely hot environments. The researchers have cultured P. profundus in a laboratory setting, providing it with a nutrient-rich broth. They are monitoring the bacterial population over time using a spectrophotometer to measure turbidity (cloudiness), which correlates with cell density.

Questions:

a) Outline typical phases of bacterial growth reflected in the turbidity data of the P. profundus culture.
b) Explain the way the growth rate of P. profundus be affected by changes in temperature.

Key Facts 3.3a: Growth of microbes

Growth requirements

Physical growth requirements

Physical aspects include temperature, pH, and osmotic pressure.

- **Temperature**

According to the temperature requirements there are **psychrophiles** (0-20^{O}C), **mesophiles** (25-45^{o}C) and **thermophile** (50-70^{o}C). A temperature of 75^{o}C for 20 minutes will kill vegetative cells but not endospores.

- **pH**

According to pH, microorganisms are divided into:

Neutrophiles: Microorganisms that grow in pH between 6.5 to 7.5

Acidophiles: Microorganisms that grow in pH as low as 1.6

Alkalophiles: Microorganisms live in basic environments such as the ocean, pH about 8.2

- **Osmotic pressure/ oxygen-respiratory requirements**

Some microbe require oxygen to survive and are called **aerobes** or **obligate aerobes**. Example: **Bacillus**, **Pseudomonas**, **Mycobacterium**.

Other are **anaerobes** for whom oxygen is actively toxic are called obligate **anaerobes**.

Microbes that can grow in the presence and the absence of oxygen are **called facultative**

Some microorganism can tolerate the presence of oxygen but not use it for growth, these are termed **aerotolerant-anaerobes**.

Other microbes can use oxygen, but only if the concentration is less than that found in the ambient air (20%), these microbes are called **Microaerophilic**.

Chemical growth requirement

Microorganisms are cultured in water to which appropriate dissolved nutrients are added. These nutrients fall into three categories: energy sources, cell structural components (elemental requirements), and Miscellaneous growth factors.

- **Energy sources**

Organic energy sources: sugar, starches, fats, proteins, glucose, acetic, glutamic, lactic acid; used by most bacteria, all fungi and protozoa.

Inorganic energy sources: NH_4^+, Nitrate, Iron, H_2S; only bacteria used these sources.

Light-photoautotrophs: Cyanobacterium

- **Elemental requirements/ cell structural components**

Macro and micro or trace elements or nutrients; including but not limited to: C, H, O, P, K, I, N, S, Ca, Fe, Mg.

- **Miscellaneous growth factors**

- Vitamins: B1, biotin, pyroxidine (B_6), B_{12} may be needed.
- Amino acids: get from proteins digest; example: casein (milk protein), peptone (meat protein).
- Purines and pyrimides (Nitroge bases)
- Heme (Fe_2O_3)

Growth phases

- **Lag Phase**

This initial phase is characterized by cellular activity but not growth. A small group of cells are placed in a nutrient rich medium that allows them to synthesize proteins and other molecules necessary for replication. These cells increase in size, but no cell division occurs in the phase.

Application in real life

Example: When you inoculate a fresh culture medium with bacteria, they don't immediately start dividing. This is the lag phase, where they're adapting to the new environment.

Food Spoilage: When food is contaminated with bacteria, there might be a lag phase before noticeable spoilage occurs as the bacteria adjust to the food's conditions.

Antibiotic Treatment: After starting antibiotic treatment, there might be a lag phase before the bacteria population starts to decline significantly.

- **Exponential (Log) Phase**

After the lag phase, bacterial cells enter the exponential or log phase. This is the time when the cells are dividing by binary fission and doubling in numbers after each generation time. Metabolic activity is high as DNA, RNA, cell wall components, and other substances necessary for growth are generated for division. It is in this growth phase that antibiotics and disinfectants are most effective as these substances typically target bacteria cell walls or the protein synthesis processes of DNA transcription and RNA translation.

Application in real life

Example: This is the period of rapid growth where the bacterial population doubles at a constant rate.

Food Spoilage: Once the lag phase is over, bacteria in food can enter the log phase, leading to rapid spoilage and the production of toxins.

Infections: During an infection, bacterial populations can enter the log phase, causing rapid symptom onset and disease progression.

- **Stationary Phase**

Eventually, the population growth experienced in the log phase begins to decline as the available nutrients become depleted and waste products start to accumulate. Bacterial cell growth reaches a plateau, or stationary phase, where the number of dividing cells equal the number of dying cells. This results in no overall population growth. Under the less favorable conditions, competition for nutrients increases and the cells become less metabolically active. Spore forming bacteria produce endospores in this phase and pathogenic bacteria begin to generate substances (virulence factors) that help them survive harsh conditions and consequently cause disease.

Application in real life

Example: As nutrients are depleted and waste products accumulate, growth slows down. The number of new cells produced equals the number of cells dying.

Food Preservation: Techniques like refrigeration or pickling aim to slow down bacterial growth and keep them in the lag or early log phase, preventing spoilage.

Chronic Infections: Some chronic infections may involve a prolonged stationary phase where the host's immune system and the bacterial population are in a state of equilibrium.

- **Death Phase**

As nutrients become less available and waste products increase, the number of dying cells continues to rise. In the death phase, the number of living cells decreases exponentially and population growth experiences a sharp decline. As dying cells lyse or break open, they spill their contents into the environment making these nutrients available to other bacteria. This helps spore producing bacteria to survive long enough for spore production. Spores are able to survive the harsh conditions of the death phase and become growing bacteria when placed in an environment that supports life.

Application in real life

Example: As conditions deteriorate further, the number of viable bacteria begins to decline significantly.

Antibiotic Treatment: Effective antibiotic treatment aims to drive bacterial populations into the death phase, eliminating the infection.

Food Spoilage: Eventually, food may enter the death phase of bacterial growth, but it might still be unsafe to consume due to the presence of toxins produced during earlier growth phases.

Key Facts 3.3b: Culturing and observation of microbes in the laboratory

Culturing methods

1. Streak plate method

The **streak plate method** is a laboratory technique used to isolate a **pure culture** of microorganisms from a sample that contains multiple species. This method allows the microbiologist to obtain distinct colonies of a single species for further study, testing, and identification.

Objective of the Streak Plate Method

- To **isolate individual bacterial colonies** from a mixed culture.
- To separate different microorganisms that are present in a sample.
- To obtain **pure cultures** for subsequent biochemical tests or antibiotic sensitivity tests.

Principles of the Streak Plate Method

- The technique relies on **diluting** the microbial sample over the surface of an agar plate using a sterile inoculating loop.
- The loop is used to spread the sample over the agar surface in a **series of streaks**. As the loop moves across the agar surface, fewer and fewer microorganisms are transferred with each successive streak.
- The result is the development of distinct bacterial colonies that arise from individual bacterial cells, which grow into visible, isolated colonies.

Materials Needed

- **Agar plate** (petri dish containing solidified agar medium, such as nutrient agar or MacConkey agar).

- **Sterile inoculating loop** or a sterile swab.
- **Microbial sample** (e.g., a liquid culture or sample from a clinical or environmental source).
- **Bunsen burner** (for sterilizing the inoculating loop).
- **Incubator** (to allow microbial growth at an appropriate temperature).

Steps in the Streak Plate Method

- **Prepare the agar plate**:

Pour the agar medium into a petri dish and allow it to solidify at room temperature.

- **Sterilize the inoculating loop**:

Heat the inoculating loop in the Bunsen burner flame until it is red hot. Let it cool for a moment before using it to prevent killing the microorganisms with excessive heat.

- **Inoculate the loop**:

Dip the sterilized loop into the microbial sample (either by dipping it into the liquid culture or by touching it to a bacterial colony on a solid medium).

- **Streak the plate**:

Gently streak the loop over the surface of the agar in a **zigzag motion** to spread the microorganisms over a small section of the plate.

Sterilize the loop again after the first streak to prevent cross-contamination, and make additional streaks. The second streak should intersect with the first but spread out further across the plate.

Repeat the process one or two more times, each time sterilizing the loop between streaks. Each streak should cover a larger area of the plate, but fewer microorganisms should be transferred with each streak.

- **Incubation**:

After streaking, the plate is incubated in an incubator at an appropriate temperature (usually around 37°C for most bacteria) for 24 to 48 hours.

During incubation, individual bacterial cells from the sample will multiply to form visible colonies.

- **Examine the plate**:

After incubation, examine the plate for **isolated colonies**. Each isolated colony should be derived from a single bacterial cell and will appear as a separate cluster of microorganisms.

Colony morphology can be used to help identify the bacterial species based on shape, size, color, texture, and other characteristics.

Types of Streaking Patterns

- **Quadrant streaking** (most common): The plate is divided into four sections, and the inoculating loop is used to streak the culture in a series of quadrants, each crossing into the previous one.
- **Radiant streaking**: The loop is streaked in a star-shaped pattern from the center of the plate.
- **Continuous streaking**: A continuous zigzag streak pattern is made across the surface of the plate, typically used for more delicate organisms that require slower growth.

Advantages of the Streak Plate Method

- **Simplicity**: It is easy to perform and requires minimal equipment.
- **Cost-effective**: Inexpensive compared to other methods of culturing microbes.
- **Isolation of pure cultures**: It is effective in isolating individual colonies, which are essential for accurate identification and further study.

Limitations of the Streak Plate Method

- **Skill required**: Proper technique is essential for obtaining isolated colonies. Inexperienced users may inadvertently create mixed colonies or fail to separate species.
- **Not ideal for very low concentration samples**: In samples with very low microbial density, it may be difficult to isolate colonies.
- **Time-consuming**: The process of streaking and incubating can take 24 to 48 hours, and isolation may take multiple attempts.

2. Pour plate method

The **pour plate method** is a microbiological technique used to isolate and enumerate microorganisms, as well as to obtain pure cultures from a mixed sample. This method involves mixing a microbial sample with molten agar and pouring it into a petri dish, allowing microorganisms to grow both on the surface and throughout the agar medium.

Objectives of the Pour Plate Method

- The objective of pour plate method are:
- To **isolate** and **enumerate** microorganisms from a mixed culture.
- To obtain **pure cultures** for further identification and study.
- To determine the **total microbial population** in a sample by counting colony-forming units (CFUs).
- To study microbial growth in a solid medium.

Principles of the Pour Plate Method

In this method, the microbial sample is diluted (usually serially) and then added to molten agar (typically around 45–50°C) that is in a liquid state. The sample and agar mixture is then poured into a petri dish. Once the agar solidifies, individual microorganisms are trapped within the agar medium, where they will grow into visible colonies.

Microorganisms can grow both **on the surface** and **within** the agar, making it useful for estimating the total number of viable cells in a sample.

Materials Needed

- **Molten agar medium** (e.g., nutrient agar, Mac Conkey agar, etc.).
- **Sterile test tubes** for serial dilution (if needed).
- **Petri dishes** for pouring the agar.
- **Inoculating loop** or pipette for transferring the sample.
- **Bunsen burner** (for sterilizing the loop or other tools).
- **Incubator** (to allow microbial growth at the appropriate temperature).

Steps in the Pour Plate Method

- **Prepare the Agar Medium**:

Prepare the agar medium (e.g., nutrient agar) and heat it to its molten state (around 45-50°C). If needed, allow the molten agar to cool slightly, but do not let it solidify before use.

- **Prepare Dilutions**:

For accurate isolation, dilute the microbial sample by performing serial dilutions in sterile saline or buffer (this is especially important when the sample is expected to have a high concentration of microorganisms).

- **Inoculate the Sample**:

After diluting the sample, use a sterile pipette or loop to transfer a small volume (e.g., 1 ml) of the sample or dilution into a sterile petri dish.

Ensure that the sample is transferred evenly to maximize colony growth.

- **Mix with Molten Agar**:

Add the molten agar medium (already cooled to about 45-50°C) to the petri dish containing the sample.

Gently swirl or rotate the petri dish to mix the sample evenly with the molten agar.

- **Allow to Solidify**:

Let the agar-solidified plate cool and solidify in an upright position at room temperature (this typically takes 5-10 minutes).

- **Incubation**:

Once solidified, the plates are incubated in an incubator at the appropriate temperature (usually around 37°C for bacteria) for 24 to 48 hours.

- **Examine the Plates**:

After incubation, examine the petri dish for the growth of individual colonies. Colonies will be visible both on the surface and inside the agar medium.

- **Colony Counting**:

Count the **colony-forming units (CFUs)** on the plate. The number of colonies can be used to estimate the concentration of microorganisms in the original sample.

Isolated colonies are also studied for identification purposes.

Advantages of the Pour Plate Method

- **Isolation of Microorganisms**:

Allows for the isolation of individual colonies from a mixed culture, enabling further study of specific organisms.

- **Enumeration of Microorganisms**:

It can be used to estimate the number of viable microorganisms (CFUs) in a sample, which is important in microbiological quality control and environmental monitoring.

- **Allows Growth of Microorganisms in Different Environments**:

The method provides an opportunity to study microbial growth in solidified agar, where some microorganisms may grow better in a semi-solid environment.

- **Works for Anaerobes**:

Some microorganisms, particularly **anaerobic bacteria**, can grow better inside the agar medium, as it offers an anaerobic environment beneath the surface.

Limitations of the Pour Plate Method

- **More Labor-Intensive**:

The method requires more preparation and handling compared to other methods, such as the streak plate method.

- **Not Ideal for All Microorganisms**:

Some microorganisms may be inhibited by the heat of molten agar or may not grow effectively within the medium.

- **Colonies may overlap**:

Since colonies can grow both on the surface and inside the agar, some colonies may overlap, making colony counting more difficult in dense samples.

- **Potential for Uneven Distribution**:

Incomplete mixing of the microbial sample with the molten agar can lead to uneven distribution of microorganisms and less accurate colony isolation.

Applications of the Pour Plate Method

- **Isolation of Pure Cultures**: Useful for isolating specific bacterial species from mixed cultures.
- **Microbial Enumeration**: Commonly used to count microorganisms in water, food, or clinical samples (e.g., determining microbial load in a food sample).
- **Studying Microbial Growth Patterns**: To examine how microorganisms grow both on the surface and within solid media.
- **Determining Colony Morphology**: Helps in identifying microorganisms based on colony characteristics such as size, color, shape, and texture.

Observation of microbes

The **observation of microbes** in the laboratory is a crucial part of microbiological analysis. It helps microbiologists identify, study, and understand the characteristics and behavior of microorganisms such as bacteria, viruses, fungi, and protozoa. Proper techniques and tools are essential for obtaining accurate and meaningful observations. Below are the key aspects to consider when observing microbes in a laboratory setting.

Preparation for Observing Microbes

Before beginning the observation of microbes, certain preparations are necessary:

a) Sample Collection

Samples are collected from various sources such as the environment (air, soil, water), clinical samples (blood, urine, saliva), or culture plates.

Ensure that samples are properly handled and stored to prevent contamination or degradation of the microbes.

b) Staining of Microbes

Microscopic observation of microorganisms often requires **staining** because most microbes are transparent and difficult to see without staining.

Common Staining Methods:

- **Gram Staining**: Differentiates bacteria into Gram-positive (purple) and Gram-negative (pink) based on their cell wall structure.
- **Acid-Fast Staining**: Used for identifying Mycobacterium species (e.g., tuberculosis).
- **Endospore Staining**: Helps identify bacterial endospores.
- **Simple Staining**: Uses basic dyes like methylene blue to color the cell wall and make microbes visible.
- **Negative Staining**: Stains the background, leaving the microorganisms transparent for contrast.

c) Slide Preparation

- **Wet Mounts**: Used to observe live microorganisms, such as protozoa or motile bacteria. The sample is placed on a slide and covered with a cover slip.
- **Smears**: For stained samples, a thin smear of the sample is spread on the slide, air-dried, and then heat-fixed.

Microscopes Used for Observing Microbes

The **microscope** is the primary tool for observing microorganisms. There are several types:

a) Light Microscope

- **Compound Light Microscope**: The most commonly used microscope in microbiology, which can magnify up to 1000x to 2000x.
- **Bright-Field Microscopy**: This is the most common technique, where light passes through the specimen and into the objective lenses.

- **Phase Contrast Microscopy**: Enhances contrast in unstained cells, making it useful for live cell observation.

b) Electron Microscope

- **Transmission Electron Microscope (TEM)**: Provides detailed internal images of cells, allowing for magnification up to 1,000,000x.
- **Scanning Electron Microscope (SEM)**: Provides detailed 3D images of the surface of microorganisms, offering high magnification (up to 500,000x).

c) Dark-Field Microscope

A specialized type of light microscope that makes unstained microorganisms visible against a dark background, improving contrast for certain types of microbes.

Key Observations Under the Microscope

a) Colony Morphology

- **Form**: The shape of individual colonies (e.g., circular, irregular, filamentous).
- **Elevation**: How the colonies rise above the surface (e.g., flat, convex, umbonate).
- **Margin**: The edges of the colonies (e.g., entire, lobate, undulate).
- **Surface**: Texture of the colony surface (e.g., smooth, rough, wrinkled).
- **Color**: The color of the colonies can provide clues about the microbial species.

b) Cellular Morphology

- **Shape**:

- **Cocci** (spherical), **bacilli** (rod-shaped), **spirilla** (spiral-shaped).

Specialized shapes like **vibrios** (comma-shaped) or **spirochetes** (flexible spirals).

- **Size**: Microbes range from about 0.2 µm (bacteria) to over 100 µm (some protozoa).

- **Arrangement**: The way cells group together (e.g., pairs, chains, clusters, or single cells).
- **Motility**: Using techniques like **wet mounts**, observe whether the microorganisms are moving. Bacteria may use flagella or other appendages for movement.
- **Internal Structures**: In stained preparations, observe the presence of specific structures like endospores, nuclei (in eukaryotic cells), or flagella.

c) Gram Staining Results

- **Gram-Positive**: Appears purple under the microscope (e.g., *Staphylococcus*).
- **Gram-Negative**: Appears pink (e.g., *Escherichia coli*).

d) Presence of Special Features

- **Endospores**: Some bacteria, like *Bacillus* and *Clostridium*, form endospores that resist heat and harsh conditions.

- **Capsules**: Some microorganisms have a capsule that appears as a clear halo around the cell.
- **Flagella**: Some microbes exhibit motility due to flagella, which may be observed using special stains or techniques.

Methods for Enhancing Microbial Observation

a) Use of Stains and Dyes

Different stains can be used to highlight specific microbial structures or characteristics, such as the cell wall, nuclei, or specific organelles.

Fluorescent Dyes: These dyes can bind to specific microbial components and emit light under ultraviolet (UV) light, which helps in identifying specific microorganisms or structures.

b) Special Techniques

- **Immunofluorescence**: Uses antibodies tagged with fluorescent dyes to detect specific antigens on microbial surfaces.
- **Phase Contrast and Differential Interference Contrast (DIC)**: Allow viewing live microorganisms without staining, enhancing visibility and contrast.

Factors Affecting Microbial Observation

- **Resolution**: The ability of a microscope to distinguish between two close points. High-resolution microscopes provide clearer and more detailed images.
- **Lighting**: Proper lighting is essential to ensure that microorganisms are visible. Adjust the light source to optimize visibility.
- **Sample Preparation**: The method used to prepare the sample will affect how well the microorganism is observed (e.g., wet mount vs. stained slide).
- **Magnification**: Adjust the objective lenses to the correct magnification level, depending on the size of the microorganism.

Documentation and Reporting

- **Record Observations**: Take detailed notes on the characteristics of the microorganisms, including shape, color, size, and arrangement.
- **Photomicrography**: Some microscopes are equipped with cameras for taking high-resolution images of microorganisms, which can be used for documentation and further analysis.

The process of growing microorganisms in a controlled laboratory environment, are fundamental to numerous real-world applications across various fields. Here are some key examples:

1. Medical Diagnostics:

Identifying Infectious Agents: Culturing bacteria, fungi, and other microorganisms from patient samples (blood, urine, sputum, etc.) allows for their identification and helps determine the appropriate course of treatment.

Antimicrobial Susceptibility Testing: Cultured microorganisms can be tested against different antibiotics to determine which ones are most effective in inhibiting their growth. This information is crucial for guiding treatment decisions and combating antibiotic resistance.

2. Food Safety and Quality Control:

Detecting Foodborne Pathogens: Culturing techniques are used to detect and identify harmful bacteria (e.g., Salmonella, E. coli, Listeria) in food samples, ensuring food safety and preventing outbreaks of foodborne illnesses.

Monitoring Food Spoilage: Culturing techniques can be used to monitor the growth of spoilage microorganisms in food products, helping to determine shelf life and prevent food waste.

3. Industrial Applications:

Biotechnology: Microbial cultures are essential for the production of various biotechnological products, including antibiotics, vaccines, enzymes, and biofuels.

Bioremediation: Culturing techniques are used to isolate and study microorganisms that can degrade pollutants, aiding in the development of bioremediation strategies for environmental cleanup.

4. Research and Development:

Fundamental Research: Microbial cultures are used extensively in research to study microbial physiology, genetics, metabolism, and interactions with the environment.

Drug Discovery: Culturing techniques are used to screen for new antimicrobial agents and to study the mechanisms of drug action.

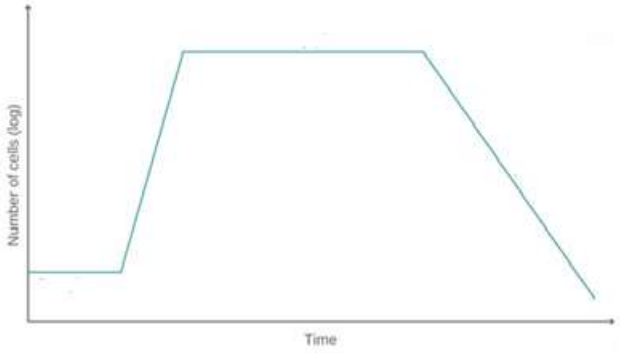
5. Environmental Monitoring:

Assessing Water Quality: Culturing techniques are used to monitor the presence of indicator microorganisms in water samples, providing insights into water quality and the potential for contamination.

Monitoring Soil Health: Culturing techniques can be used to assess the diversity and abundance of microorganisms in soil, providing information on soil health and ecosystem function.

Activity 2: Guided Practice

Task 29: Observe the curve of living organisms' growth and answer the below question.



Question: Identify different phases of growth of living organisms on the above curve on time function.

Activity 3: Application

Task 30: Read and answer the below question:

A local food processing company reports a possible contamination in their dairy products after customers complain of severe gastrointestinal symptoms. Samples of the suspect yogurt and cheese are sent to the microbiology laboratory for culturing and analysis.

As biologist:

Explain the goal for laboratory culture and analysis.

How did this investigation help the company?

Formative Assessment

1. Define the term microbiology

2. Briefly, explain the contribution of microbiology in the following domain:

a) In agriculture

b) In pharmaceutic

3. Describe the contribution of Louis Pasteur and Robert Coach in microbiology.

4. The following are harmful effects of microbes except:

a) Causing malodour in home textiles, clothing, and footwear.

b) Conservation of food in food industries

c) Dirtying of paint, which can be difficult and costly to remove.

d) Causing diseases to plants and animals.

4. Answer by true or false by using T or F respectively at the end of statement.

a) The bacteria has a true nucleus as one of general characteristics

b) Viruses can live free without host organism.

c) Fungi are eukaryotic, non-vascular, non-motile and heterotrophic organisms, reproduce by spore

d) Algae are eukaryotic organisms, photosynthetic, terrestrial and reproduce by spores.

e) Protozoa are single-celled organisms, heterotrophic, may live free or in parasitic, reproduce by binary fission or budding

5. You are asked to grow bacteria in laboratory, what are different physical and chemical growth requirements you have to consider in advance?

6. Discuss the application of microbial culture and its observation on the below domains:

a) Medical Diagnostics

b) Food safety and quality control

c) Environmental monitoring

7. How can antibiotics be used to treat bacterial infections?

8. Design a hypothetical experiment to test the effectiveness of a new disinfectant against a specific type of bacteria.

9. Explain the reason why viruses differ from other microorganisms.

10. Based on objectives, differentiate pour plate from the Streak Plate Method.

11. After observation of microbes in laboratory, the microbiologist must provide document and report. Explain the components of documentation and reporting.

Points to Remember

Microbiology is the study of microorganisms or microbes, a diverse group of generally minute simple life form that include bacteria, archaea, algae, fungi protozoa and viruses.

The microbiology began with the development of the microscope

The microscope was the first provided by a Dutch Antonie Van Leeuwenhoek in the middle of 1670.

Louis Pasteur in French, Robert Koch in Germany and others in the later 1800 established the importance and benefits of microbes to humans,

The benefits of microbes are diverse in the different domains such as: in agriculture industries, in health and medicine industries, in maintenance of the environment, and in pharmaceutic and biotechnology industries.

Furthermore microbes can have harmful to human such as: causing malodour in home textiles, foot wear and clothes, dirtying of paint, and causing diseases.

The different microbes that are already known are: bacteria, viruses, fungi, algae, and protozoa.

To grow the microbes require the following related parameters: physical requirements (T^0, pH, and oxygen), chemical requirements such as nutrients, energy sources and vitamins.

The microbes have different growth phases such as: lag phase, exponential phase, stationary phase and death or declining phase.

Microbes can be cultivated and observed in laboratory by using streak plate method and pour plate method.

Self-Reflection

Read the statements across the top. Put a check (V)in a column that best represents your level of knowledge, skills and attitudes.

My experience Knowledge, skills and attitudes	I don't have any experience doing this.	I know a little about this.	I have some experience doing this.	I have a lot of experience with this.	I am confident in my ability to do this.
Remember history of microbiology					
Outline importance of microbes					
Describe characteristics of bacteria					
Describe characteristics of virus					
Describe characteristics of algae					
Describe characteristics of fungi					
Describe characteristics of protozoa					
Identify growth requirements of microbes					
Illustrate growth phase of microbes					

My experience Knowledge, skills and attitudes	I don't have any experience doing this.	I know a little about this.	I have some experience doing this.	I have a lot of experience with this.	I am confident in my ability to do this.
Carry out culturing and observation of microbe in the laboratory					

2. Fill in the table above and share results with the trainer for further guidance.

Areas of strength	Areas for improvement	Actions to be taken to improve
1. **2.** **3.**	**1.** **2.** **3.**	**1.** **2.** **3.**

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