



TVET LEVEL II



BASIC EDUCATION

Basic Sciences

TRAINER MANUAL



Approved by:  Workforce
Development
Authority



USAID
FROM THE AMERICAN PEOPLE



Acknowledgements

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	• Safety, Health and Sustainable Environment • Personal Development and Career Guidance	E.g. Food Crop Production and Processing includes the following modules: 1. Food Crop Production 2. Small Scale Post-Harvest Operations 3. Growing Medium 4. Food Safety and Sanitation 5. Food Preservation and Storage 6. Flour Processing
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Organization of the Training Manuals

For each module there is a Trainer Manual and a Trainee Manual. These manuals, based on the curricula for each subject, are divided into Learning Units, and each Learning Unit includes 3 – 5 Learning Outcomes. The learning outcomes make up the essential skills, knowledge and attitudes to be acquired by trainees. To make the Trainee Manual more user friendly, Unit and Topic are used respectively for Learning Unit and Learning Outcome. The number of hours per training module varies, ranging between 30 and 120 hours.

Teaching & Learning Methodology of RTQF Level II 2 TVET Materials

The teaching and learning methodology used in the materials is based in experiential and adult learning. Activities are designed to engage trainees, build upon what they know and learn and provide them with opportunities to build their skills in the classroom and in the workplace. More specifically, guiding principles in the development of the manuals include:

- ▶ Building on participants' knowledge, skills and experiences
- ▶ Facilitating a learning process through active engagement of participants rather than through lecturing
- ▶ Providing opportunities to practice – inquiry based and hands on practice, both in the classroom and workplace
- ▶ Using simple and clear language
- ▶ Connecting to the real world: use local resources and the environment for learning
- ▶ Promoting critical thinking through properly debriefing activities and asking questions that get learners to think, analyze, relate issues and topics to their own lives and come up with solutions

- ▶ Applying social inclusion principles: Finding ways to include all types of youth (and trainers) – males and females; different cultural/ethnic/religious backgrounds, people with disabilities (PWD); people with different types of health status ...
- ▶ Encouraging risk taking – promote questioning and being free to explore
- ▶ Promoting habits of mind that support life-long learning: curiosity and wonder, open mindedness, creativity

These principles are reflected in the layout and flow of activities in the manuals:

1. **Key Competencies:** Table found at the beginning of each Learning Outcome that describes the main knowledge, skills and attitudes to be gained by the end of the activities.
2. **Self-Assessment:** Conducted at the beginning and end of each Learning Unit to get a sense of trainees' knowledge and skills going into it and what they have gained by the end of the Learning Unit (and steps they need to take to further their understanding and skills).
3.  **Getting Started Activity:** Typically, a quick activity or questions to 1) give the trainer a sense of trainees' existing knowledge and skills; 2) spark the interest of trainees in the topic; 3) introduce the objectives and key competencies of the topic.
4.  **Problem Solving Activity:** A challenging activity to get trainees engaged and to learn through discovery instead of memorization of facts. A variety of teaching and learning methodologies are used, including individual and group work such as reading real life work-based scenarios and answering accompanying questions to activities such as identifying proper tools and equipment from the school workshop to conduct a certain activity. Following the sharing of responses, the trainer guides trainees through the content and processes being introduced.
5.  **Guided Practice Activity:** Building on the concepts and skills gained in the Problem Solving Activity, the trainer guides trainees through practical examples.
6.  **Application Activity:** Consolidates trainees' knowledge and skills through a real-life application of the topic in the classroom, community or workplace. Trainees are given more independence in applying what they have learned.
7. **Key Facts boxes:** Throughout the Trainee Manual, one will find Key Facts boxes. These contain the main information or content for a given Learning Outcome. They are there for the trainees' reference and are used throughout the different types of activities.

8.  **Points to Remember:** List of the top key learning points or “take-aways” from the topic.
9.  **Formative Assessment:** Questions and activities to assess trainees’ level of understanding of the concepts introduced.
10.  **Summative Assessment:** Based on the integrated, real life situation approach used in other TVET levels, this is done at the end of every module for agricultural modules and, with some variations, at the end of each Learning Unit for Basic Education and Soft Skills modules.
11.  **Self-Reflection:** Trainees re-take the Self-Assessment given at the beginning of the Learning Unit and identify their strengths, challenges and actions to improve their level of competence.

The Trainer and Trainee Manuals are meant to be used in conjunction with each other and are well coordinated through the headings and labelling of activities. The trainer will always be able to refer trainees to specific activities by the coordinated numbering system. For instance, a specific exercise might be labelled Topic 1.2 Task 2. The Topic is the number of the Learning Outcome and the task is the specific exercise to be done. The Key Facts are also numbered for easy reference. These nor the Self-Assessment tables are in the Trainer’s Manual so the trainer should have a copy of both manuals.

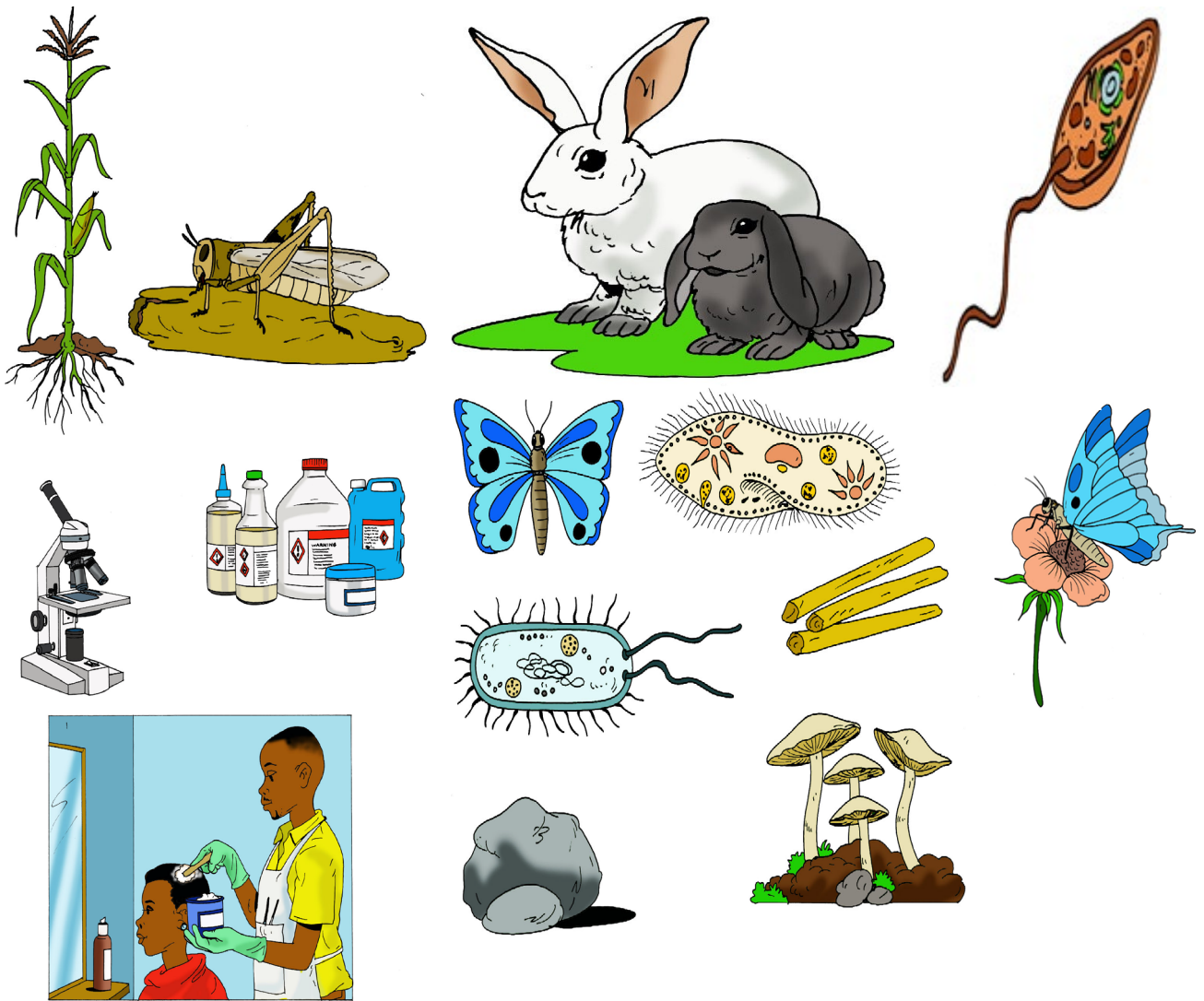
The Trainer’s Manual includes answers (or guidelines to the trainer as appropriate) to Formative and Summative Assessments as well as to problems given throughout the activities. Summative Assessments are not included in the Trainee’s Manual. These are meant to be used as a guide for those who will be developing a context-appropriative Summative Assessment at the end of the Module or Learning Unit. Basic Education and Soft Skills modules include Summative Assessments at the end of every Learning Unit while the technical modules include it only at the end of the module.

Lastly, there is a section in the Trainer’s Manual for additional information to the trainer that includes either specific information or references to information that can help them deepen their understanding of the particular content.

BASIC SCIENCES AT WORKPLACE

Learning Units	Learning Hours	Learning Outcomes
Learning Unit 1: Use key concepts about living things	30	1.1 Use the classification of living things
		1.2 Use a microscope to describe the smallest unit
		1.3 Describe the smallest unit of living things
		1.4 Handle chemical products in accordance with safety concerns for the tissues of living things
Learning Unit 2: Apply basic genetic principles	30	2.1 Select farming species
		2.2 Apply hybridization techniques to plants
		2.3 Apply hybridization techniques to animals
Learning Unit 3: Chemistry – Atomic and Molecular Structure	30	3.1 Explain the difference between elements, compounds and mixtures
		3.2 Explore linkages between the atomic structure and the positions of elements on the periodic table
		3.3 Apply knowledge of atomic structure to formation of chemical bonds
Learning Unit 4: Apply basic physical concepts at the workplace	30	4.1 Measure physical fundamental and derived quantities at the workplace
		4.2 Use measuring instruments at the workplace
		4.3 Use physical laws at the workplace

Learning Unit 1: Use key concepts about living things



Learning Outcomes

By the end of the Learning Unit, trainees will be able to:

- 1.1 Use the classification of living things
- 1.2 Use a microscope to describe the smallest unit
- 1.3 Describe the smallest unit of living things
- 1.4 Handle chemical products in accordance with safety concerns for the tissues of living things

Learning Unit 1 Self-Assessment

1. Ask trainees to look at the Unit 1 illustration in the Trainee's Manual and discuss what they see. Ask them what topics they think this unit will include based on careful observation of the illustrations. After some brainstorming, reveal the headings of the main topics that will be covered in this unit.
2. Ask each trainee to fill out the **self-assessment** at the beginning of this unit. The purpose of the self-assessment is to be aware of what every trainee knows or does not know about the unit. At the end of this unit, ask each trainee to do a **self-reflection**, repeating the self-assessment of Unit 1 and recognizing strengths and areas that need improvement. The self-assessment is not a test!

Learning Outcome 1.1: Use classification of living things

	Objectives: By the end of the learning outcome, trainees will be able to: a. Define and list the characteristics of living things b. Compare living and non-living things and deduce their differences c. Apply hierarchical classification to classify living things according to their features
	Time Required: 7 hours
	Learning Methodology: Pair work, group work, brainstorm, trainee presentation
	Materials Needed: scissors, scotch tape, markers/chalk, pictures of living and non-living things, flipchart, reference materials that shows examples of how living things are classified
	Preparation: ☐ Arrange classroom and organize all materials. ☐ Gather specimens and print out pictures of examples of living things from the 5 kingdoms as needed. ☐ Prepare cards for Topic 1.1 Task 2 under Problem Solving Activity. ☐ Gather any reference materials you have that shows the classification of living things. If no materials are available, have trainees use their phones to access the internet or use any available computers at the school to research the classification of given examples.
	Cross Cutting Issues: ✓ Environment and Sustainability: collecting specimens of living things ✓ Peace and Values Education: working together in groups ✓ Inclusive Education: allocating tasks during the learning process so all are included ✓ Gender Balance: in forming working groups
	Prerequisites: ▶ Names of living and non-living things

Key Competencies:

Knowledge	Skills	Attitudes
1. Define living things	1. Compare living and non- living things and deduce their differences	1. Curious/investigative: Use the classification of living things to explore the diversity of life forms in our environment
2. List the characteristics of living things	2. Apply hierarchical classification to classify living things according to their features	2. Analytical: Recognize the characteristics of living things and the methods used to study life



Steps:



Getting Started: What do we know and where are we going?

1. Ask trainees to turn to the pictures in *Illustration 1.1* under the Getting Started activity. In pairs, ask them to look at the pictures and classify them in two columns, one for living things and the other for non-living things.
2. Ask trainees to discuss how they decided which things are living and which are not. Ask for volunteers to share what was discussed in the various pairs.
3. Clarify any misconceptions about the chart's title and components. Close by presenting a summary of the results classifying living or non-living things.



Problem Solving Activity

1. Ask trainees to observe the illustration in the Trainee's Manual under **Topic 1.1 Task 1**. In small groups of 3 or 4, ask them to answer the questions about living things and their characteristics.
2. Ask volunteers to share their group's answers.
3. Explain the five kingdoms of living things using **1.1 Key Facts**. Refer trainees to **1.1 Key Facts** in their manuals. (Protista, Monera, Animalia, Plantae, Fungi).
4. Also, discuss the characteristics of living things (see **1.1 Key Facts**), referring back to the various responses regarding similar characteristics of the organisms shown in the pictures. These include:
 - Nutrition
 - Respiration

- Movement
- Excretion
- Growth
- Reproduction
- Sensitivity



Guided Practice Activity

1. Divide class into small groups to do **Topic 1.1 Task 2**. Give each group 2 sets of card (prepared beforehand). Make sure that the order within each set is mixed up:

Set 1: continent, country, province, district, sector, cell, village/family

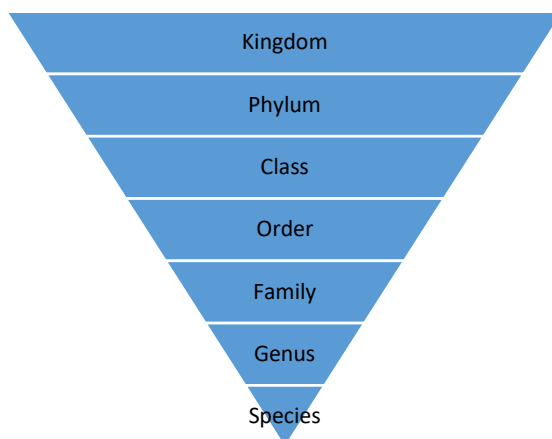
District	Country	Cell	Province	Village/ Family	Continent	Sector
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Set 2: kingdom, phylum, class, order, family, genus, species

Family	Phylum	Kingdom	Species	Class	Genus	Order
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2. Ask trainees to read the list of words on the cards provided, starting first with **Set 1** and then **Set 2**. (Note: they most likely will not know the order for the classification of living things but let them try.) They should then do the following:
 - a. Arrange the words in each set in order of size from the largest to the smallest. Justify your answer.
 - b. Compare the 2 sets. What similarities do they have?
3. Ask groups to share their responses. Explain that just like the way we can organize groups of people into categories such as continent, country, province, etc., scientists organize all living things into categories. This is known as **taxonomy**. It is a hierarchical classification system, starting with the largest group of kingdom and gradually getting down to a smaller group known as species.
4. Divide trainees into small groups to do **Topic 1.1 Task 3**. Provide them with specimens/drawings/photographs of a grasshopper, butterfly, ant, termite, tick, spider, millipede, crab, scorpion and centipede). In groups, respond to the questions below:
 - a. Which of these specimens belong in the same kingdom? Which kingdom do they belong to?
Answer: Animalia
 - b. What do these specimens share in common? (notice the body features: number, presence or absence of some parts). Present the findings to the whole class.
Possible Answers: have multiple legs, hard shell/exoskeleton, antennae, 3 main parts: head, thorax (section between head and abdomen with wings and legs), abdomen)
 - c. Group these animals according to their **similarities** and **differences**.
Possible Answers: Could be done by number of legs, if they fly, color

- Ask groups to share their responses and discuss. Explain to the class that as we differentiate more and more between living things, we are classifying the living thing from Kingdom down to Species. It is important to remember the order of the categories, from largest to smallest.



Give the example of the human being to explain how the group gets smaller and smaller as one moves from kingdom to species. Explain that the scientific name is created by putting the genus and species together and italicized or underlined:

General Classification Category	Specific Classification Category for a Human Being	Description of what is in the Category
Kingdom	Animalia	All animals
Phylum	Chordata	Animals with a backbone
Class	Mammalian	Animals with a backbone and hair
Order	Primate	Mammals with hands and feet
Family	Hominidae	Apes, primitive & modern humans
Genus	Homo	Primitive and modern humans only
Species	sapiens	Modern humans only
Scientific Name	<i>Homo sapiens</i>	Put the genus and species together to create the scientific name. ¹

- Refer trainees to **1.2 Key Facts** in their manuals for definitions and information discussed above about classification.
- Ask learners to turn to **Topic 1.1 Task 4** in their manuals. Explain that the table shows the classification system for five different living things: maize, a human, a two-spot ladybird, a

¹ Kadhila, N. Unit 1: Characteristics and classification of living organisms in *NSSC Biology Module 1*. Cambridge University Press. Retrieved from https://assets.cambridge.org/97805216/80547/excerpt/9780521680547_excerpt.pdf

mountain gorilla and a honeybee. Their task is to use the information in the table to answer the questions. This activity will help them become more familiar with the classification system.

	Maize	Human being	Two-spot ladybird	Mountain gorilla	Honeybee
Kingdom	Plantae	Animalia	Animalia	Animalia	Animalia
Phylum	Spermatophyta	Chordata	Arthropoda	Chordata	Arthropoda
Class	Angiosperms	Mammalia	Insecta	Mammalia	Insecta
Order	Graminale	Primate	Coleoptera	Primate	Hymenoptera
Family	Graminae	Hominidae	Coccinellidae	Hominidae	Apidae
Genus	<i>Zea</i>	<i>Homo</i>	<i>Adalia</i>	<i>Gorilla</i>	<i>Apis</i>
Species	<i>mays</i>	<i>sapiens</i>	<i>bipunctata</i>	<i>gorilla beringei</i>	<i>mellifera</i>
Scientific name	<i>Zea mays</i>	<i>Homo sapiens</i>	<i>Adalia bipunctata</i>	<i>Gorilla beringei</i>	<i>Apis mellifera</i>

- Which of the living things belong to the same kingdom? (**Answer:** human being, two-spot ladybird, mountain gorilla and honeybee all belong to Animalia Kingdom)
 - What order does the two-spot ladybird belong to? (**Answer:** Coleoptera)
 - What is the genus of the honeybee? (**Answer:** *Apis*)
 - Which of the living things have similarities to each other? Explain. (**Answer:** The human being and the mountain gorilla are the most similar as they belong to the same kingdom, phylum, class, order and family. The two-spot ladybird and the honeybee share the same kingdom, phylum and class but nothing beyond that.)
 - Which of the items is most different from the others? Explain. (**Answer:** Maize is different, belonging to the Plantae Kingdom. All the others belong to the Animalia Kingdom.)
 - Write the scientific names for each of the living things in the table. (**Answer:** see the last line above in table. This is blank in the Trainee's Manual to fill in.)
- Explain that it would be impossible to remember the kingdom, phylum, class, order, family, genus and species for every living thing! Ask trainees where they think they can find such information. (**Possible answers:** science books and other reference materials, internet search)
 - Ask trainees to turn to the person next to them and discuss reasons why it might be important to classify living things. Have them share their responses and discuss. Supplement their responses with those listed in **1.2 Key Facts**.



Application Activity

1. Explain to trainees that they are going to use any reference materials/books available or the internet to research the classification of various living things. Let them know that they might find more detailed ways of classifying living things. (For example, many of the categories they have been introduced to are further divided into sub categories. They might see the word “clade” for phylum and class).
2. Divide the class into small groups of 4-6 people and have them turn to **Topic 1.1 Task 5**. Assign each group a living thing to classify. For example: domestic pig, domestic cow, African rice, ... Ask them to:
 - a. Fill in the classification table for their animal or plant. **Possible answers:**

	Domestic pig	Domestic cow	African rice
Kingdom	Animalia	Animalia	Plantae
Phylum	Chordata	Chordata	Spermatophyta
Class	Mammalia	Mammalia	Liliopsida
Order	Artiodactyla	Artiodactyla	Cyperales
Family	Suidae	Bovidae	Poaceae/Gramineae
Genus	<i>Sus</i>	<i>Bos</i>	<i>Oryza</i>
Species	<i>scrofa</i>	<i>taurus</i>	<i>Glaberrima steud.</i>
Scientific name	<i>Sus scrofa</i> ²	<i>Bos taurus</i> ³	<i>Oryza glaberrima steud.</i> ⁴

- b. Identify another animal or plant that has a similar classification. (**Possible answers:** A warthog is similar to a domestic pig with the same kingdom, phylum, class, order and family. An African buffalo is similar to a cow with everything the same through family. Maize is similar to African rice, again through family.)

² Domestic Pig. (n.d.). In Wikipedia. Retrieved November 5, 2019, from https://en.wikipedia.org/wiki/Domestic_pig

³ Cattle. (n.d.). In Wikipedia. Retrieved November 5, 2019, from <https://en.wikipedia.org/wiki/Cattle>

⁴ Classification for Kingdom Plantae Down to Genus Oryza L (n.d.). In United States Department of Agriculture, Natural Resources Conservation Service. Retrieved November 5, 2019 from <https://plants.usda.gov/java/ClassificationServlet?source=display&classid=ORYZA>



Points to Remember

- Living things have properties related to nutrition, respiration, movement, excretion, growth, reproduction and sensitivity
- Living things are classified into: Kingdom > Phylum > Class > Order > Family > Genus > Species
- Kingdom is the largest category, and then gets narrowed down all the way to species.
- The five main Kingdoms are Protista, Monera, Animalia, Plantae and Fungi.
- Importance of classification: Classification helps us understand the relationships, similarities and differences between living things.



Formative Assessment

1. Complete the passage below by choosing the words from this list:

excretion	growth	sensitivity	movement
nutrition	organisms	reproduction	respiration

- Living things are often called _____.
- All living things release energy from their food in a process called _____, which happens inside their cell.
- Some of the energy is used for _____, which usually happens more quickly in animals than in plants.
- The food from which the energy is released is taken into the body in a process called _____.
- All living things get bigger as they get older. This process is called _____.
- The production of young is called _____.
- Waste substances are removed from organisms by the process of _____.
- The seventh characteristic shown by all living organisms is _____, which means that they react to things around them.

Answers: a. (organisms), b. (respiration), c. (movement), d. (nutrition), e. (growth), f. (reproduction), g. (excretion), h. (sensitivity).

2. A car needs petrol and air in order to move. It produces waste gases.
 - a. Which characteristics of living organisms are similar to those of a car?
 - b. Why is a car not a living organism?

Answers: a) excretion and movement b) A car cannot grow, reproduce...

3. A scientist has the correct information to classify a cat but it is out of order. Help the scientist put the information in order from the largest category of information to the smallest. Finally, write the scientific name of the cat.⁵

Order: Carnivora
Phylum: Chordata
Class: Mammalia
Kingdom: Animalia
Genus: Felis
Species: Catus
Family: Felidae

Answer:

Kingdom	Animalia
Phylum	Chordata
Class	Mammalia
Order	Carnivora
Family	Felidae
Genus	<i>Felis</i>
Species	<i>catus</i>

Scientific name: _____ (**Answer:** *Felis catus*)

Further Information for the Trainer

- ❖ Until quite recently living organisms were divided into two kingdoms: animals and plants. But this system of classification had some problems. Some unicellular organisms were put among animals whereas they have chlorophyll and feed by photosynthesis. Mushrooms were put among plants whereas they do not have chlorophyll and the structure of their cells differ from that of plant cells. Bacteria were put among plants whereas they do not have a true nucleus. To solve these problems, in 1969, the American biologist WHITTAKER suggested a scheme which divides living organisms into five kingdoms: Animalia, Plantae, Protista, Fungi and Monera. See the Key Facts in the Trainee's Manual for information about the 5 kingdoms and the characteristics and classification system of living things.
- ❖ For information on how certain characteristics help scientists identify the phylum, class, etc. of a cat, see: Arnold, K. (April 23, 2018). *The Seven Levels of Classification for a Domestic Cat*. Retrieved from <https://sciencing.com/type-animal-octopus-8403441.html>. It can help explain how the categories get smaller and smaller as one moves down from kingdom to species.

⁵ Arnold, K. (April 23, 2018). *The Seven Levels of Classification for a Domestic Cat*. Retrieved from <https://sciencing.com/type-animal-octopus-8403441.html>

Learning Outcome 1.2: Using a microscope to describe the smallest unit



Objectives: By the end of the learning outcome, trainees will be able to:

- a. Explain how to use a hand lens and a microscope to magnify objects
- b. Describe the parts of a light microscope and their respective functions
- c. Draw and calculate the magnification of different specimens



Time Required: 8 hours



Learning Methodology: group work, pair work, drawing, discussion

Materials Needed:



- Hand lens
- Light microscopes, microscope slide, cover slip, razor blade, dropper, mounted needle, iodine/methylene blue
- Onion bulb, leaves, insects, mouldy bread and other objects to look at with a hand lens or microscope

Preparation:



- ☐ Prepare slices of bread so they have mould.
- ☐ Prepare temporary slides with plant or animal tissue.
- ☐ Prepare room in advance so each group will have microscope and hand lens.

Cross Cutting Issues:



- ✓ **Standardization culture:** Following proper procedures when using a microscope
- ✓ **Peace and values education:** Working collaboratively in small groups
- ✓ **Gender:** Form balanced groups of males and females

Prerequisites:

- ▶ Knowledge of the parts of plants
- ▶ Be able to measure the length of an object

Key Competencies:

Knowledge	Skills	Attitudes
1. Describe the hand lens and light microscope	1. Recognize and use a hand lens to observe specimens	1. Be curious about how a hand lens and microscope can magnify objects
2. Identify the parts of a light microscope and their respective functions	2. Use a microscope	2. Be attentive while using a light microscope
3. Describe the procedure in using a microscope	3. Draw and calculate the magnification of biological diagrams	3. Be accurate when calculating magnification



Steps:



Getting Started: What do we know and where are we going?

1. Ask trainees to observe the displayed illustrations in **Topic 1.2 Task 1** of the Trainee's Manual and name them.

Answers:

A: hand lens

B: Light microscope

C: Electron microscope

D: Cover Glass

E: Slides

F: Microscope immersion oil

2. Place the following objects in front of the class: a very heavy textbook, a heavy bag of sand, a microscope, a set of 3 glasses. Ask 4 volunteers to come in front of the class. Ask them to walk from the front of the classroom to the rear with one of the objects. Tell the students to observe the volunteers and be ready to comment on how they carried out the instructions.
3. When each of the 4 has reached the rear of the room, ask the class to comment on how the objects were carried and to recommend any changes if need be. Ask if the microscope was carried as a trained scientist would carry it. If yes, how was it done? If no, ask another volunteer to demonstrate how it should be carried.

Answer: Carefully carry a microscope to your workbench or desk using both hands. Put one hand on the arm and one hand on the base of the microscope.

4. Explain that in this topic we are going to be learning how to use tools such as the hand lens and microscope to examine small things.



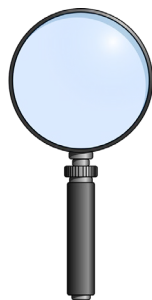
Problem Solving Activity

Topic 1.2 Task 2: Discover magnification / microscopy and its importance

1. Divide trainees into small groups. Give each group an insect specimen and a small piece of mouldy bread, a hand lens and a microscope. (Depending on the availability of hand lenses and microscopes, trainees will need to take turns using these.)

2. Tell them their task is to complete the following in the order the tasks are given:
 - a. Observe the insect and bread with your eyes. Draw what you see in your notebook.
 - b. Observe the insect and bread with the hand lens. Again, draw what you see.
 - c. Observe the insect and bread through the microscope (the trainer will help you set it up). Now draw what you see.
 - d. Answer the following questions:
 - i. What is the difference between your three drawings? (**Possible answer:** each one became more detailed as more could be seen with the hand lens and then the microscope).
 - ii. How can a hand lens or microscope be useful? (**Possible answer:** It enables one to see more and more details as the magnification becomes stronger. This can help people such as scientists study living and nonliving things to understand their features.)
 - iii. Based on this activity , what do you think microscopy is? (**Possible answer:** See **1.3 Key Facts.**)
3. Ask groups to show their drawings to the other groups and discuss the responses to the questions. Discuss the terms and definitions found in **1.3 Key Facts.**
4. Hold up the hand lens and/or ask trainees to look at the hand lens in front of them. Ask if they can identify any of the parts. How do they think it is able to magnify an object?

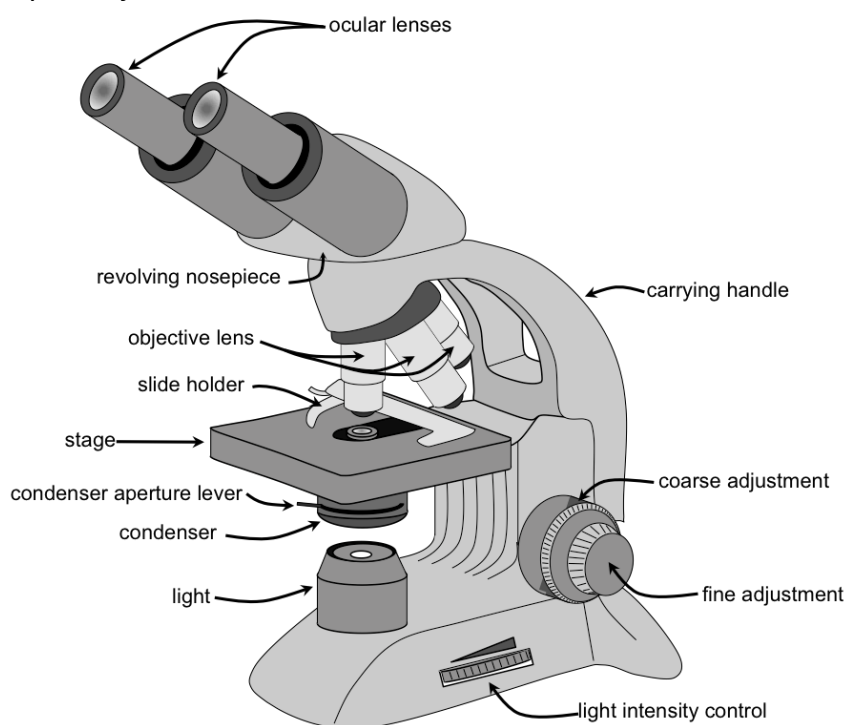
Answer: The hand lens is comprised of two main parts : the glass lens and the body. The glass has a convex shape (curved outwards) which bends the rays of light, resulting in a magnified object.



5. Ask trainees to look at the microscope. What parts can they name? After a few minutes, have them turn to the illustration of the labeled parts of a microscope. Ask them to find each part on the real microscope. When they have done that, ask them to do some research on the internet or with available books to find out what function each part plays. Review the parts and their functions together after giving them some time to find the information themselves. Refer trainees to **1.4 Key Facts** for information on the microscope and hand lens.

Also explain that the type of microscope we will be using is called a **light microscope**. It is also known as a **compound microscope** because there are several lenses instead of one as in a **simple microscope**. There are also other types of microscopes such as **electron microscopes** that are much more powerful and can provide more detail and clarity of an object or specimen.

Instead of using a light source, electron microscopes use beams of charged particles (electrons) to help magnify an object.



6

6. Demonstrate how to properly use the microscope, using the information in **1.4 Key Facts** to guide you. Remind them of the function each part plays. Let them practice using the insect or mouldy bread from the previous activity.
7. Have participants turn to the next illustration, the microscope without the labeled parts. They should label each part while also looking at the real microscope to help them remember the different parts.



Guided Practice Activity

1. Divide trainees into small groups but have each trainee do the written parts in their notebooks. Ask trainees to turn to **Topic 1.2 Task 3** and perform the observation activities using a hand lens, various insects, moss plants and plants leaves.
 - a. Place the hand lens above the insect, and then look down through the hand lens.
 - b. Move the hand lens closer to your eyes, and then further away from your eyes. What do you notice?

⁶ User:Thebiologyprimer. (2014, April 21). *Parts of a microscope (english)* [Illustration]. Wikimedia Commons. [https://commons.wikimedia.org/wiki/File:Parts_of_a_Microscope_\(english\).png](https://commons.wikimedia.org/wiki/File:Parts_of_a_Microscope_(english).png)
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Possible Answer: As you move the lens closer to the object, the image becomes smaller. As you move the lens further away, the image becomes larger.

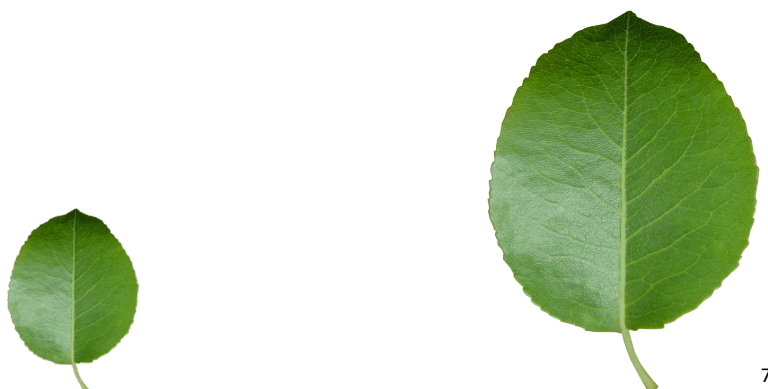
- c. Repeat this experiment using a moss plant. Identify the small green leaves and the tiny transparent rhizoids (roots of moss).
- d. Make a simple drawing of a moss plant and label the structures you have identified; for example, the leaves, rhizoids, and stem.

Possible answer: An image resembling this one.



- 2. Ask trainees, in their groups, to turn to **Topic 1.2 Task 4** and perform the observation of a plant leaf using the indicated procedures:
 - a. Measure a small leaf using a ruler. Make a drawing of it using the same dimensions in your notebook.
 - b. Mark on a clear piece of scotch tape millimetres and centimetres. Stick it across the center of a hand lens.
 - c. Hold the hand lens with one hand and place the leaf specimen on a bench.
 - d. Bring the hand lens over the leaf specimen and look down through the hand lens.
 - e. Move the lens up and down slightly until the image is in focus.
 - f. Measure the size of the image by using your “scotch ruler” on the hand lens.
 - g. Draw the image of the leaf as seen through the lens, using the same dimensions.
 - h. Discuss with the person next to you how you can calculate the magnification. Calculate the magnification of your drawing, using the dimensions of the actual specimen and that magnified image.

Example of an answer:



Actual size = 2.3cm

Image size = 4.9cm

Magnification of drawing = image size/actual size = $4.9\text{cm}/2.3\text{cm} = 2.1\text{X}$

3. Ask each group to share their results. Emphasise that magnification is calculated by dividing the image size by the actual size.
4. Explain to the trainees they are now going to get more experience handling the microscope and drawing magnified objects.
5. Divide trainees into pairs or groups. Give each group a microscope and a slide with a specimen on it. Don't tell them what it is! They will have to guess as the activity proceeds.
Note: Prepare the slides beforehand with any object.
6. Ask trainees to manipulate the microscope as indicated in **Topic 1.2 Task 5** in the Guided Practice section of their manuals. Demonstrate each step as they try to follow steps and do it on their microscope.
7. Trainees should draw the object in their notebooks as they see it under the microscope. Ask them how they think magnification is calculated when using a microscope. After some answers, explain that with a microscope, one needs to consider the objective lens and the power of the eyepiece. The power of the eyepiece is normally 10X. The power of the objective lens will depend on the microscope and what it is set to (4X, 10X, 40X, 100X). To get the total magnification, multiply the power of the objective lens by the power of the eyepiece. Have them calculate the total magnification for the specimen they are observing. (Example: If the eye piece has a power of 10X and the objective lense is 40X, the total magnification is $10\text{X} \times 40\text{X} = 400\text{X}$. Have them change the power of the objective lens and calculate the total magnification each time.
8. Answer any questions and refer trainees to **1.4 Key Facts** for the formulas on total magnification. Take them through the examples given.

⁷ Images from Pixabay.com; License: <https://pixabay.com/service/license/>



Application Activity

1. Explain to trainees that they are going to get more practice in using the microscope and hand lens. Divide the class into small groups. Quickly review how to use the hand lens and the microscope by asking for volunteers to explain to the class.
2. Tell trainees now they are going to prepare their own slides. They are going to look at a piece of onion. They should follow the procedure in **Topic 1.2 Task 6** in their manuals. Guide them as they prepare the slide.
3. Have trainees examine the specimen using different objective lenses, draw the images they see, and calculate the total magnification for each objective lens used.
4. **Supplemental Activity:** If there is time remaining or if trainees are taking turns using the microscope, they can use a hand lens (or microscope) to look at an insect specimen such as dead mosquito or fly. They should draw what they see and calculate the magnification accordingly.



Points to Remember

- A hand lens and microscope are used to magnify an object or specimen so you can see more details.
- Always handle a microscope with care!
- Follow the proper procedure when fixing a specimen on a slide and on the microscope.
- Magnification (m) = h'/h where h' is the image height and h is the object height.
- Total magnification, when using a microscope is the power of the objective lens (4X, 10X, 40X and 100X) multiplied by the power of the eyepiece, usually 10X.

Formative Assessment

1. Label the parts of a compound light microscope in the diagram below:



Answer:



⁸ User:Thebiologyprimer. (2014, April 21). *Parts of a microscope (english)* [Illustration]. Wikimedia Commons. [https://commons.wikimedia.org/wiki/File:Parts_of_a_Microscope_\(english\).png](https://commons.wikimedia.org/wiki/File:Parts_of_a_Microscope_(english).png)
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⁹ User:Thebiologyprimer. (2014, April 21). *Parts of a microscope (english)* [Illustration]. Wikimedia Commons. [https://commons.wikimedia.org/wiki/File:Parts_of_a_Microscope_\(english\).png](https://commons.wikimedia.org/wiki/File:Parts_of_a_Microscope_(english).png)
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2. A leaf measures 4 cm in length. A diagram of the leaf that appears in a Biology textbook measures 12 cm. By how much has the leaf been magnified?

Answer: Magnification of drawing = $12\text{cm}/4\text{cm} = \times 3$

3. A group of learners uses a microscope to view a cell. The eyepiece lens magnifies objects 10X and the objective lens that they use magnifies 25X. What is the total magnification?

Answer: Total magnification = $10\text{X} \times 25\text{X} = 250\text{X}$

4. Look at the drawing of a bee. If the bee's actual length is 1.5 cm, how many times has it been magnified in the drawing?



Answer: Magnification of drawing = $\text{image length}/\text{actual length} = 4\text{cm}/1.5\text{cm} = 2.6\text{X}$

¹⁰ Image from Pixabay.com; License: <https://pixabay.com/service/license/>

Learning Outcome 1.3: Describing the smallest unit of living things

	Objectives: By the end of the learning outcome, trainees will be able to: - Explain the main parts of the smallest unit. - Match parts of the cell with their functions in a table format. - Compare the structure of animal and plant cells. - Make an observation of human cheek cells and epidermal cells of an onion on a prepared slide.
	Time Required: 7 hours
	Learning Methodology: group work, pair work, presentation, brainstorming and field trip
	Materials Needed: - Hard boiled eggs, knife, prepared slides, light microscope, iodine, onion, slides and covers, cotton wool bud, methylene blue stain - Drawings of animal and plant cells
	Preparation: ☐ Prepare 6 hard-boiled eggs. ☐ Gather materials – microscopes, slides and covers, etc. before class. ☐ Make arrangements for trainees to do research in school library, in the classroom with available books or on the internet.
	Cross Cutting Issues: ✓ Inclusive education: through using appropriate resources for all learners ✓ Standardization culture: by showing standard microscopes and accurate equipment ✓ Gender equity: in assigning tasks equally to learners in a group
	Prerequisites: ▶ Characteristics of living things ▶ Examples of living things

Key Competencies:

Knowledge	Skills	Attitudes
1. Name the main parts of the smallest unit of life	1. Compare the structure of animal and plant cells	1. Be observant in noticing the differences between plant and animal cells
2. Explain the meaning of smallest unit of life	2. Use a microscope to make an observation of human cheek cells and epidermal cells of an onion on a prepared slide	2. Be thorough in research of plant and animal cell parts.
3. Describe the function of the parts of the cell	3. Differentiate between animal and plant cells while looking at them with a microscope	3. Be patient while trying to observe cell parts under a microscope



Steps:



Getting Started: What do we know and where are we going?

1. Put trainees in groups according to the number of cooked eggs you have and have them turn to **Topic 1.3 Task 1** in their manuals. Explain that the egg is going to represent the smallest unit of life.
2. Guide trainees and ask them to make a transversal dissection of a cooked egg and have them answer the questions in their manuals.

Answer:

- a. The egg represents a cell in a living organism.
 - b. **A:** cytoplasm **B:** nucleus **C:** cell membrane
3. Review what the parts of the egg represent with the trainees. Explain that this topic is going to focus on the smallest part of a living organism, the cell.



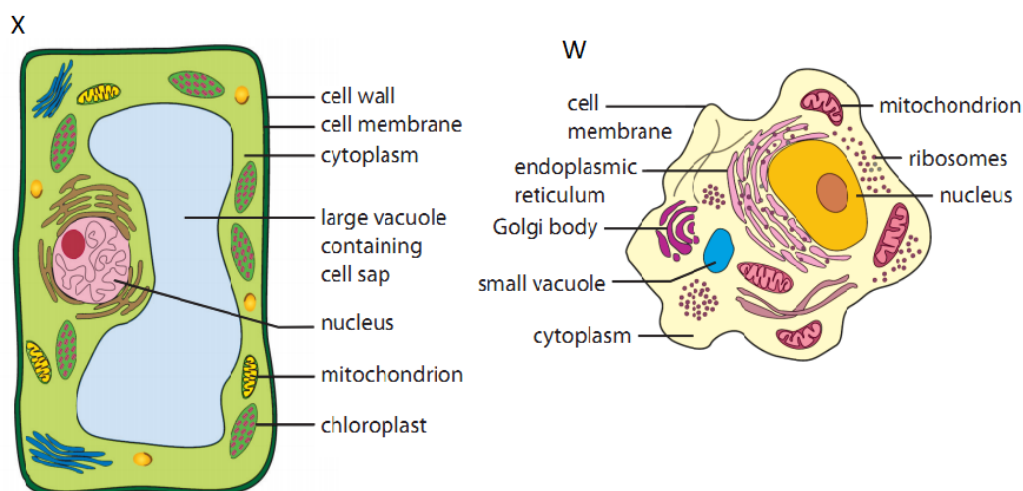
Problem Solving Activity

1. Provide biological diagrams (or refer to biological drawings in Trainees' Manual) that represent plant and animal cells seen under an electron microscope. Ask trainees to observe them in groups and answer the questions set on them.

Answers:

1. See **1.5 Key Facts** that describes differences and similarities between plant and animal cells.

2. See labeled cells below.



2. Review trainees' responses to the cell parts together. As you go through each part, explain its function. Refer trainees to **1.5 Key Facts** and review the definitions together.



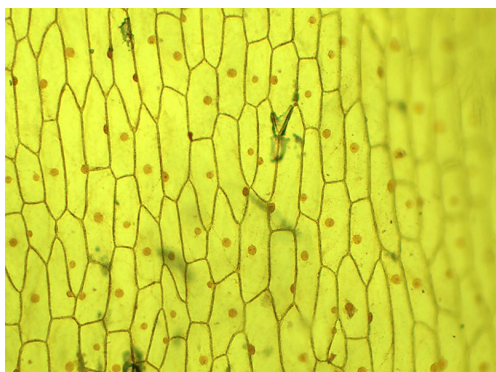
Guided Practice Activity

1. Prepare a light microscope in advance. If a microscope is not available, display the diagram of plant and animal cells.
2. Guide trainees to prepare microscope slides using onion epidermis and mouth cheek epithelium cells. Have them follow the instructions in **Topic 1.3 Task 3** in their manuals.
3. Ask trainees to observe cells from onion epidermis and from mouth cheek epithelium under the light microscope.

Possible Answers:

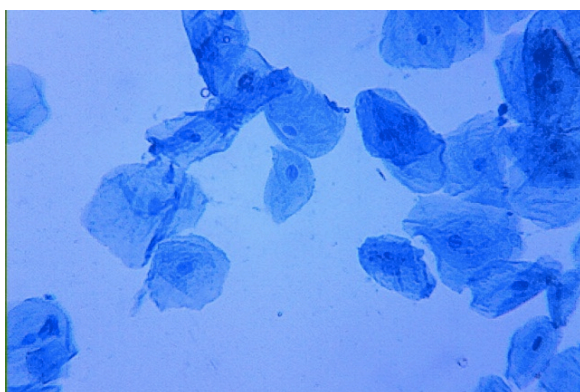
Onion epidermis cell:

Iodine is used in preparing the slide because it helps you see the parts of the cell more clearly.



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Cheek epithelium cell:



12

4. Discuss the different cell structures that can be seen with the microscope and explain the function of each part.



Application Activity

1. Ask trainees to prepare a microscope slide using an onion cell and observe it using a light microscope. They should draw what they see and try to name the parts.
2. Ask trainees to use the library or the internet and identify the functions of each of the following cell organelles: cell membrane, cytoplasm, nucleus, mitochondrion, cell wall, chloroplast and vacuole.

Answers:

Cell organelle	Function
----------------	----------

¹¹ McCloughlin, T. J. (2019, October 23). *Onion epidermis high power* [Photograph]. Wikimedia Commons. https://commons.wikimedia.org/wiki/File:Onion_epidermis_high_power.jpg

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¹² Elsbernd, J. (2012, April 15). *Human cheek cells*.

Flickr. <https://www.flickr.com/photos/codonaug/6936088770>

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cell membrane	The cell membrane surrounds the cytoplasm and keeps the cell contents in place. It is selectively permeable, which means that it can control the movement of substances into and out of the cell.
cytoplasm	Cytoplasm is a medium in which cell organelles and other substances such as starch granules, fat droplets, glycogen and dissolved substances are suspended.
nucleus	The nucleus plays an important role when the cell divides to make new cells. It contains the hereditary, or genetic, information that is passed from parents to their offspring during reproduction.
cell wall	The cell wall is a rigid structure found around the outside of plant cells. The cell wall gives the plant cell its shape and protects the cell.
chloroplast	Chloroplast is an organelle found in plant cells that carry out the process of photosynthesis.
vacuole	Vacuoles are organelles that usually contain fluid. Plant vacuoles usually contain water and dissolved substances, such as mineral salts and food molecules.
mitochondria	Mitochondria are the organelles inside plant and animal cells where the reactions of cellular respiration take place.

3. Ask trainees to share their responses and use the definitions above to supplement their answers. Have them look into their microscopes again to see if they can find the parts again.
4. Sum up by explaining that a cell is the basic unit of life. Review the Points to Remember with the trainees.



Points to Remember

- Cells are the basic units of all living organism.
- The structures within the cell are referred to as organelles.
- Some of the cell organelles that can be observed under the light microscope include the cell wall, cell membrane, cytoplasm, nucleus, vacuole, and chloroplasts.
- These organelles perform specific functions within the cell.



Formative Assessment

1. Which of the following statements is **not true** about cells and organelles?
 - i. Organelles are structures found in a cell that perform a specific function.
 - ii. Organelles form parts of a cell.
 - iii. Organelles are functional units of a cell.
 - iv. Organelles are cells that perform functions that cannot be done by ordinary organs.

2. Match the organelles in Column A with the correct function in Column B.

Column A	Column B
1. Nucleus	A. Living, jelly-like fluid in which reactions take place inside the cell
2. Mitochondria	B. Control centre of the cell
3. Cell wall	C. Produces energy
4. Chloroplast	D. Controls what goes in and out of the cell
5. Cytoplasm	E. The rigid structure on the outside of plant cells that keeps the shape of the cell
6. Cell membrane	F. Photosynthesis takes place here

3. In the table below, write out the differences between animal and plant cells.

Plant cell	Animal cell

Answers:

1. iv
 2. 1- B
 2-C
 3-E
 4-F
 5-A
 6-D

- 3.

Plant cell	Animal cell
Usually large	Small in size
Regular shape	Irregular shape
Has a cell wall	Has no cell wall
Has a central large vacuole	Usually has no vacuole
Has chloroplast	Has no chloroplast
Store starch, oil and protein	Store glycogen and fat

Learning Outcome 1.4: Handle chemical products in accordance with safety concerns for the tissues of living things

	Objectives: By the end of the learning outcome, trainees will be able to: - List the types of chemical hazards and examples of each - Identify examples of chemical hazards in our environment - Describe the symptoms of chemical inhalation - Apply safety precautions when handling chemicals
	Time Required: 8 hours
	Learning Methodology: group work, brainstorming, video, presentation and field trip
	Materials Needed: - Examples and/or pictures of chemical products (cleaning products, fertilizer, silica brick, urea, NPK, etc.) - Projector, computer, flipchart, marker pen
	Preparation: ☐ Select an appropriate location or video showing water pollution. ☐ Write the scenario in Topic 1.4 Task 4 on the board or flipchart so all can see.
	Cross Cutting Issues: ✓ Environment and sustainability: through exploring the effect of chemicals on living things ✓ Inclusive education: through working together in harmony despite the difference of our abilities. ✓ Standardization culture: while developing skills in handling hazardous chemicals
	Prerequisites: ▶ Cells ▶ Fertilizers and farming chemicals

Key Competencies:

Knowledge	Skills	Attitudes
1. Explain the concept of cell division	1. Apply safety precautions while handling chemicals	1. Awareness of the impact of chemicals on environment and human life
2. Explain the meaning of tissue	2. Match the chemical hazards with their consequences in environment	2. Establish habit of using protective equipment in farming activities
3. Outline the inorganic and organic industrial chemicals products	3. List the ceramic and petrochemical products	3. Describe the symptoms of airborne chemical inhalation

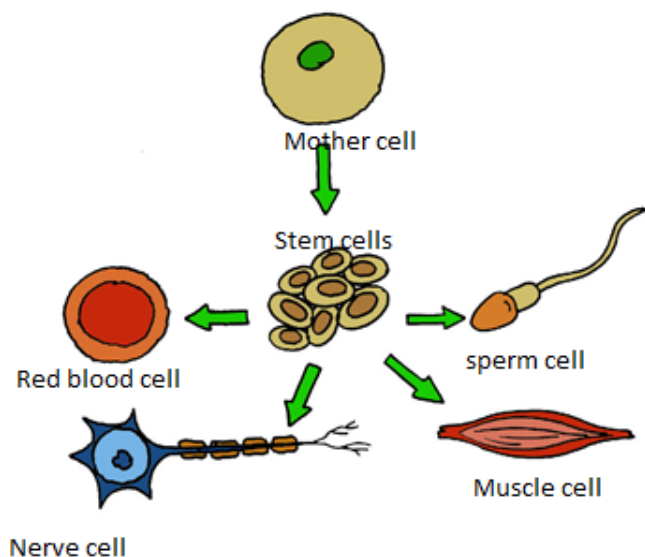


Steps:



Getting Started: What do we know and where are we going?

1. Ask trainees to find a partner, turn to **Topic 1.4 Task 1** and think about the diagram below:



- a. What are all the different types of cells in the diagram? What do they do?

Possible Answers: **Mother cell:** cell from which another cell develops; **stem cells:** cells that are able to develop into different types of cells as the body needs them; **red blood cell:** transports oxygen to body cells; **sperm cell:** sex cell that is produced in the testes of males; **muscle cell:** found in muscle tissue and produces force and motion; **nerve cell:** neurons that process and transmit information

- b. What do you think is the meaning of cell differentiation?

Answer: process where cells change to a more specialized type of cell

- c. What is tissue?

Answer: group of cells that have a similar shape and function

- d. How do our bodies react to chemical hazards?

Possible Answers: When we come into contact with chemicals that are hazardous, they can affect us in different ways – skin or eye irritation, burning, vomiting, diarrhoea, drowsiness or death

- e. How can we protect our cells/tissue from hazardous materials at the workplace?

Possible Answers: use Personal Protective Equipment such as gloves, goggles, boots, mask.

2. Let trainees pair up and discuss the questions above. Have some pairs share their responses with the rest of the trainees. Provide supplemental information as needed.
3. Introduce the learning outcome and the type of knowledge, skills and attitudes they will gain from the learning outcome. Explain that this session will focus on safety precautions while handling chemical products.

Problem Solving Activity

1. Ask trainees to observe the given chemical products (or the drawings of chemical products) in **Topic 1.4 Task 2** and carry out the activities in groups:





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- a. Identify the types of chemical products and give examples for each type.
 - b. Explain what a chemical hazard is.
 - c. Explain how the types of chemicals mentioned above can be hazardous to the environment.
 - d. Suggest which protective equipment can be used while handling hazardous chemicals.
2. The responses from the discussions may differ among groups. Refer to **1.6 Key Facts** in the Trainee's Manual and use the information while reviewing the questions together.



Guided Practice Activity

1. Explain to trainees that they are going to do library or internet research on certain chemical hazards. They are to select appropriate information and fill in the tables in **Topic 1.4 Task 3**.
2. Let trainees share their responses in a large group discussion. Use the information provided in the **1.7 Key Facts** in the Trainee's Manual to harmonize their responses.



Application Activity

1. Ask trainees to turn to the scenario in **Topic 1.4 Task 4**. You may also write it on the board or flipchart so all can see. Have them read the scenario and answer the related questions.

Scenario:

Andrew is a farmer in rural village. He always used to spray insecticides in the farm in order to kill insects, and he used different fertilizers while growing crops. While working, Andrew does not protect himself. After getting information from the Sector Agronomist, Andrew suspects that he has inhaled and exposed his skin to the chemicals in the insecticides and fertilizers. He also realizes that he is contributing to the pollution of the land and water near his farm.

2. After the small group discussion, ask each group to share their answers with the class :

¹³ User:Cjp24. (2016, June 25). *Acetylene cylinders by Air liquide* [Photograph]. Wikimedia Commons. https://commons.wikimedia.org/wiki/File:Acetylene_cylinders_by_Air_liquide.jpg
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- a. What symptoms might Andrew have if he has inhaled chemicals?

Possible Answer: See list of symptoms such as burning of the nose, eyes, lips, mouth and throat in **1.7 Key Facts**

- b. Suggest to Andrew any safety precautions he needs to follow while handling chemicals and fertilizers.

Possible Answer: Use personal protection equipment such as gloves and a face mask; immediately wash off chemical traces from the skin; follow written instructions.

- c. Explain how Andrew's activities have contributed to the pollution of the environment.

Possible Answer: insecticides and fertilizers leak into the soil and water around them. Once it gets into small streams, it eventually reaches rivers, lake and even the ocean. The chemicals can have a negative effect on other plants in the surrounding area, as well as be harmful to birds and other wildlife in the area.

- d. How can Andrew reduce his impact on the environment?

Possible Answer: Follow the instructions on the product regarding amounts and how to use the chemicals; keep insecticides and fertilizers away from water; consult with the sector agronomist or extension worker for advice on ways to farm without the use of pesticides and insecticides such as Integrated Pest Management and composting)

3. Organize a field visit study/ watch a video on a polluted water site. In groups, ask trainees to:
- Compare polluted water and non-polluted water and then present the group's findings.
 - Suggest ways of preventing water pollution.
4. Ask trainees to share their observations and suggestions on preventing water pollution. Refer trainees to **1.7 Key Facts** for supplemental information.

Note to trainer: You can have different groups working on different materials, after which they will share. If you cannot get to the polluted water site easily, you can download a video of polluted water showing the causes and effects of water pollution.



Points to Remember

- There are many types of chemical hazards you can come into contact with at home and in the workplace. Be aware of these different hazards and how you can protect yourself.
- Use personal protection equipment (PPE) to prevent chemicals from coming into contact with your body. Be sure to wear a face mask, gloves, safety goggles and other protective clothing such as solid footwear and an apron/something to cover your clothing when handling chemicals.
- We can get exposed to chemicals in different ways: inhaling or breathing them in; touching them with our skin; and swallowing.

- Protect the land, air and water around you by avoiding chemical use as much as possible and taking the right precautions when you need to use them. For example, if using insecticides or fertilizers follow the instructions on the product, don't let them come into contact with water and seek the advice of an agronomist or extension worker on how to use them responsibly.



Formative Assessment

1. Group of cells, similar in structure and function, are found in _____
 - a. Organ system
 - b. Muscles
 - c. Bone
 - d. Tissue
2. The most common way that workplace chemicals enter the body is.....
 - a. Skin (or eye) contact
 - b. Inhalation (breathing)
 - c. Swallowing (ingestion or eating)
 - d. Injection
3. Chemicals which pass through the skin are nearly always in the form of a
 - a. Solid
 - b. Liquid
 - c. Gas
4. How can chemicals enter the body through the eyes?
5. Explain the effects related to the misuse of fertilizers on the environment.
6. Describe three things to take into consideration while handling chemicals on a farm.

Answers:

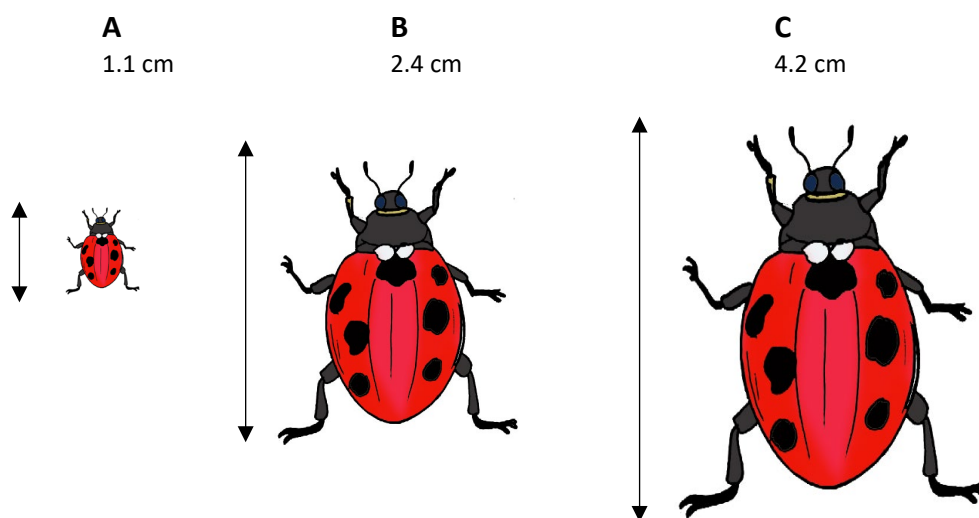
1. (d)
2. (b)
3. (b)
4. Chemicals enter the eyes by dissolving in the liquid surrounding the eyes, and larger, but probably not significant amounts, may enter the eyes if they are splashed with chemicals.
5. The misuse of chemical fertilizers cause harm to environment such as waterway pollution, chemical burn to crops, increased air pollution, acidification of the soil and mineral depletion of the soil.
6. Use personal protection equipment, Work clothes must be kept clean, Immediately wash off chemical traces from the skin / take a shower after contact with chemicals, etc.



Summative Assessment

1. Name at least three processes essential to living things and explain what they are.

2. A student examined a ladybug first by looking at it with his/her eyes (A), then with a hand lens (B) and finally with a microscope (C). The illustration below represents the sizes of the ladybug seen in each situation.



Calculate:

- The magnification of the ladybug as seen under the hand lens.
 - The magnification of the ladybug as seen under the microscope.
 - If the objective lens used on the microscope was 40X and the eyepiece has a magnification of 10X, what is the total magnification?
3. Draw a diagram of a plant cell as seen under the light microscope and label it.
4. State three examples of household/farm chemicals and at least three symptoms a person may experience if exposed to these chemicals.
5. Write short notes advising farmers on how to protect themselves while spraying insecticides and using fertilizers.

6. Integrated Situation:

Farmers in Musanze and Burera districts have been having losing their potato and bean crops to the turnip moth (*Agrotis segetum*). The insect destroys the stems of the plants.

The sector agronomist has asked you to help research the moth and educate farmers on how to control the pests. Answer the questions below:

- a. Here is the classification information for the turnip moth. Put it in the correct order.

Class: Insecta **Phylum:** Arthropoda **Order:** Lepidoptera **Family:** Noctuidae
Genus: *Agrotis* **Kingdom:** Animalia **Species:** *segetum*

- b. Examine the moth under the microscope. Name 5 parts of the microscope and their functions as you place the already prepared slide onto the microscope.

Part of the Microscope	Function of the Part
1.	
2.	
3.	
4.	
5.	

- c. The actual size of the moth is 3 cm. What is the size of the image if it is magnified 2.2X?
- d. How would a cell of the moth compare to the cell of a potato or bean plant? Draw a picture of an animal cell and a plant cell, label at least three parts and state the function of those parts.

Animal cell: 	Plant cell:
---	--

Cell Part:	Function:
1.	
2.	
3.	

- e. Even though the farmers have been weeding and tending to their fields, the moths have continued to eat the stems of the plants. The agronomist knows of an insecticide that can help get rid of the moth. She wants you to advise the farmers on how they can protect themselves while spraying insecticides.

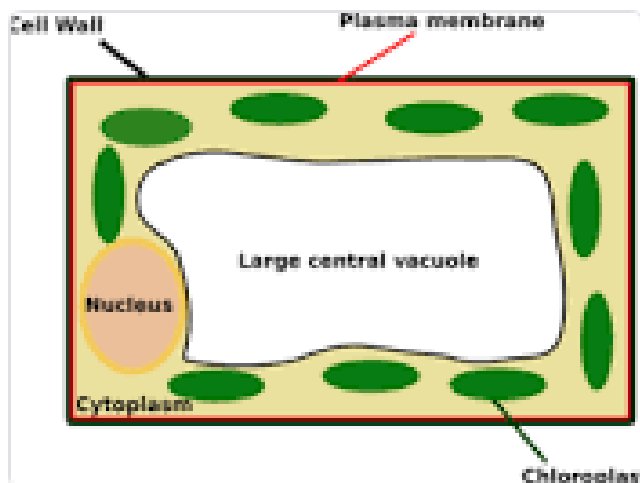
Summative Assessment: Possible Answers

1. **Reproduction** ensures the continuity of life and various species on the Earth; **excretion** maintains the natural, internal balance of an organism's system through excreting waste; **respiration** provides the energy for living organisms to perform all of the other necessary functions to maintain life; **sensitivity (irritability)** allows living things to detect and respond to changes in their environment; **nutrition** is taking in of materials from the environment for growth or energy; **movement (locomotion)** helps organisms to move from place to place searching food; **growth** uses food to produce new cells.

2.

- Magnification with hand lens = $2.4\text{cm}/1.1\text{cm} = 2.2\text{X}$
- Magnification under microscope = $4.2\text{cm}/1.1\text{cm} = 3.8\text{X}$
- Total magnification with an objective lens of 40X and eye piece of 10X = $40\text{X} \times 10\text{X} = 400\text{X}$

3.



4.

Examples of household/farm chemicals	Symptoms
• Insecticide • Pesticide • Fertilizer • Cleaning products (detergents/soaps) • Petroleum	✓ Irritation to the skin, skin rash ✓ Blurry vision and watery eyes ✓ Headache ✓ Abdominal pain, nausea and vomiting ✓ Coughing and wheezing ✓ Neurological effects

5. Use personal protection equipment (PPE) to prevent chemicals from coming into contact with your body: wear a face mask, gloves, safety goggles and other protective clothing such as solid footwear; immediately wash off any chemicals that come into

contact with your skin; follow the instructions on the products regarding amounts of fertilizer/insecticide/pesticide.

6. Integrated Situation Answers:

a. Kingdom: Animalia
Phylum: Arthropoda
Class: Insecta
Order: Lepidoptera
Family: Noctuidae
Genus: *Agrotis*
Species: *segetum*

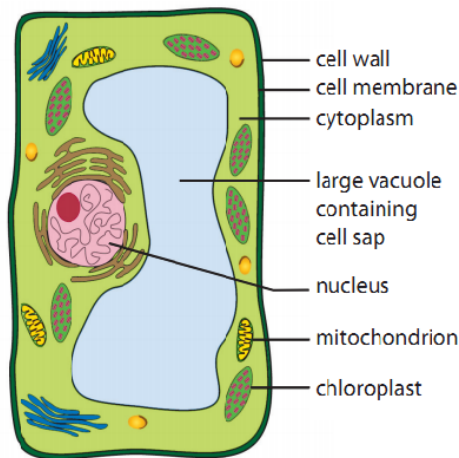
b.

Part of the Microscope	Function of the Part
1. Eye-piece lens	Lens into which user looks to see the magnified specimen
2. Arm	Provides the support to the microscope (between the base and the eyepiece)
3. Revolving nose-piece	Holds the objective lenses in place and enables the change from one objective lens to the other
4. Objective lens	Brings image into focus and magnifies it (various strengths)
5. Stage clip	Holds the slide in place
6. Stage	Flat platform where specimen on the slide is placed. It has two clips to hold the slide into position
7. Rack stop	Safety feature that prevents the stage from hitting the objective lens
8. Condenser	Concentrates light on the object on the stage
9. Illuminator (Light source)	Bulb or lamp; if the microscope has a mirror, it is used to reflect light from an external light source up through the bottom of the stage
10. Coarse focus (adjustment) knob	Brings the image into general focus
11. Fine focus (adjustment) knob	Brings the image into sharper focus.
12. Light switch (not pictured above but found on base)	Turns the light source on
13. Base	Supporting block of the microscope

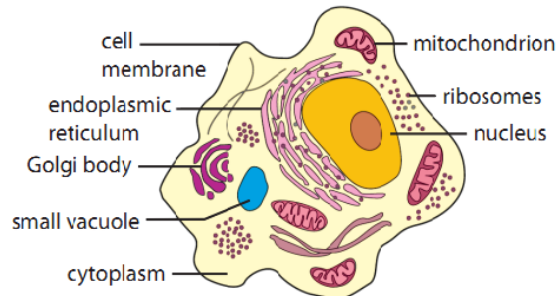
c. magnification = image height/ object height. In this case, $2.2 = \text{image height}/3 \text{ cm}$.
 So the image height is $3 \text{ cm} \times 2.2 = 6.6 \text{ cm}$

d.

X



W



- **Cell membrane:** is the thin membrane that forms the outer surface of the protoplasm of a cell and regulates the passage of materials in and out of the cell. It is found in animal and plant cells.
- **Cell wall:** Plants have a cell wall that provides structure and support to the cell. Animal cells have only a cell membrane.
- **Cytoplasm:** is all of the material within a cell, enclosed by the cell membrane
- **Nucleus:** is a membrane bound structure that contains the cell's hereditary information and controls the cell's growth and reproduction
- **Vacuole:** may contain water (especially in plant cells), waste products, and small molecules. It is a way to isolate materials that may be harmful to the cell
- **Mitochondria:** takes in nutrients from the cell, breaks it down and turns it into energy for different functions.

e.

- Use personal protection equipment (PPE) to prevent chemicals from coming into contact with your body: wear a face mask, gloves, safety goggles and other protective clothing such as solid footwear.
- Immediately wash off any chemicals that come into contact with your skin.
- Follow the instructions on the products regarding the amounts of insecticide to use.

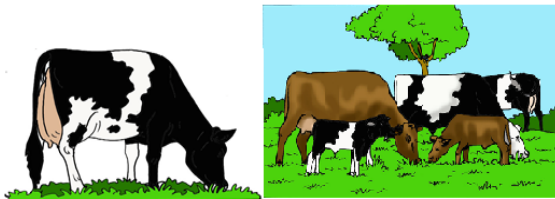


Self-Reflection

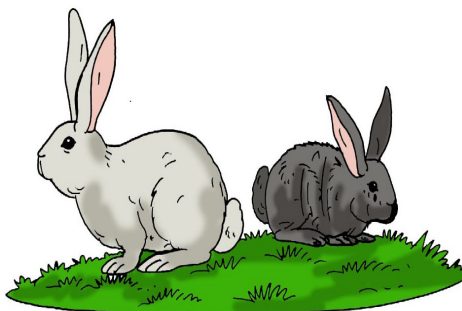
1. Ask learners to re-take the self-assessment found at the beginning of this unit. They should then fill in the table under self -reflection in the Trainee's Manual to identify their areas of strength, areas for improvement and actions to take towards improvement.
2. Discuss trainees' results with them. Identify any areas that are giving many trainees difficulties and plan to give additional support as needed (ex. use class time before you begin the next learning outcome to go through commonly identified difficult concepts).

Learning Unit 2: Apply Basic Genetic Principles

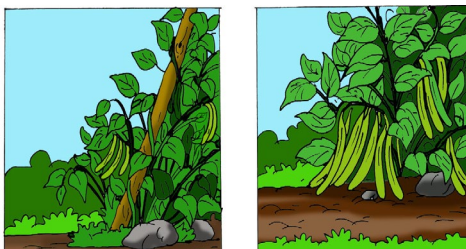
1



2



3



Learning Outcomes

By the end of this Learning Unit 2, trainees will be able to:

- 2.1** Select the farming species
- 2.2** Apply hybridization techniques to plants
- 2.3** Apply hybridization techniques to animals

Learning Unit 2: Self-Assessment

- 1.** Ask trainees to look at the illustration of the learning unit above and in the trainee manuals and discuss what they see. What topics do they think this unit will include based on the picture? Allow time for some brainstorming then present the main topics.
- 2.** Ask trainees to fill out the self-assessment at the beginning of the unit in their Trainee Manuals. Explain that the purpose of the self-assessment is to become familiar with the topics in the unit and for them to see what they know or do not know at the beginning. At the end of the unit, they will do a self-reflection, which includes re-taking the self-assessment and identifying their strengths, areas that need improvement and actions to take for improvement. The self-assessment is not a test!

Learning Outcome 2.1: Selection of farming species

	Objectives: By the end of the learning outcome, trainees will be able to: a. Explain genetics and describe key genetic terms b. Demonstrate the use of Punnett squares in crosses c. Explain Mendel's law of segregation
	Time Required: 7 hours
	Learning Methodology: Small group work, presentation, brainstorming, large group discussion
	Materials Needed: • Flipchart paper • Markers • Scotch/Masking tape
	Preparation: ☐ Select an appropriate story/scenario from the trainee book for trainees to use or create a new one that is more relevant to your context. ☐ Write the story/scenarios on flipchart so all can see or make copies for each small group.
	Cross Cutting Issues: ✓ Gender equity while forming small groups and allocating roles. ✓ Inclusiveness while preparing the activity and materials. ✓ Standardization culture while selecting appropriate species. ✓ Environment and sustainability while preparing field trip.
	Prerequisites: ▶ Basic practice of raising livestock and planting crops ▶ Basic knowledge related to specific species in the context

Key Competencies:

Knowledge	Skills	Attitudes
1. Define genetics and key genetic terms	1. Demonstrate the use of Punnett squares	1. Analytical
2. State Mendel's first law	2. Interpret the offspring from Punnett squares	2. Persistent



Getting Started: What do we know and where are we going?

1. Ask trainees to read and think about inherited traits as they complete **Topic 2.1 Task 1** in the Trainee's Manual. They will work in groups of 4.

Imagine that you are planning to meet your classmate at the airport, but you have never met. How would you describe yourself? Would you say that you are tall or short, have curly hair or straight hair; have brown eyes or green eyes?

- a. In groups of 4, let 2 of the group members to role-play the situation. While they are role playing, the other 2 group members make a list of the traits used in the description. Group members then switch roles. Each group should come up with two lists of traits that can be used to identify people the other person has never met.
- b. Put a check mark next to traits you think you think were inherited from parents.
- c. Now, individually, list 3-4 traits of your own which you think were inherited from your parents.
- d. Discuss the following two questions:
 - i. Why you look like one or both of your parents? Explain.
 - ii. How does this relate to the real-life situation of raising farming?

Answers:

- a. Lists of traits may vary but may include tall/short, chubby/slender, long/short hair, hairstyle, clothing, shoes, etc.
- b. All traits that you are born with should be checked—those that are learned or can change (like clothing or hairstyle) should not be checked.
- c. Answers may vary
- d. You look like your parents because you shared traits with them—you inherited their genes. This relates to farming because if there is a good trait you would like that cow to have babies in hopes that the babies will also have that trait—and if the cow has bad traits, those bad traits may be passed to offspring so it is best that they do not reproduce.

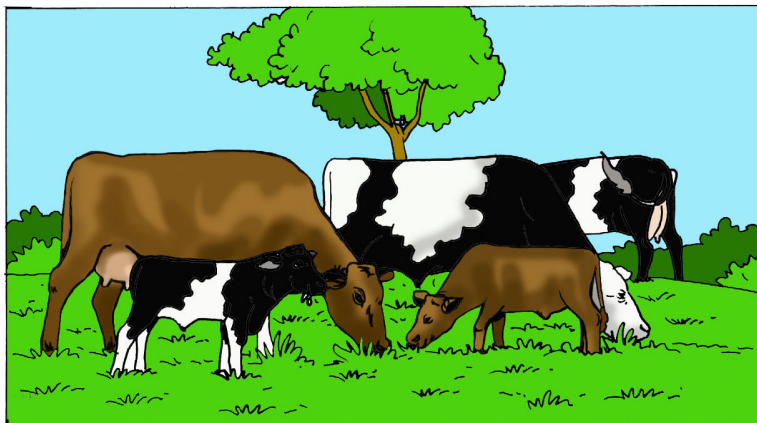
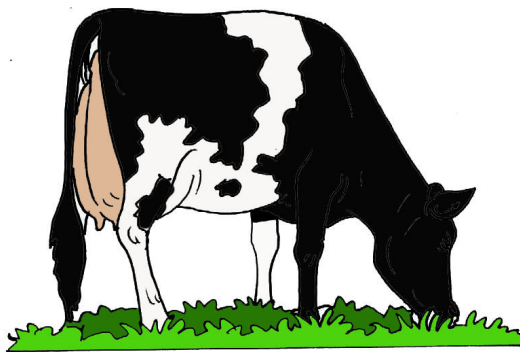
2. Have some groups share their responses with the rest of the class.

3. Introduce the learning outcome and the type of knowledge, skills, and attitudes that this learning outcome will focus on in determining how to select farming species.



Problem Solving Activity

1. Divide trainees into five groups by having them count 1, 2, 3, 4, 5. Ask groups to sit in designated places. Ask each group to observe the herd illustration and complete Topic 2.1 Task 2, in their Trainee's Manual by answering the related questions.



Observe the herd above and answer the following questions:

- a. What is the common characteristic of that herd that is most obvious?
- b. Why do the cows and calves both have that common characteristic?
- c. How is that common characteristic transmitted from cows to calves?
- d. Can you name the science that studies the transmission of physical characteristics?

Answers:

- a. The most obvious trait is that the cows are black and white mixed.
- b. Both cows and calves share this trait because the characteristic is passed from parent to offspring.

- c. The common characteristic is passed because the baby is given genes that regulate that trait from both the mother and the father—both parents contribute genes (thus traits) to babies.
 - d. This is the science of Genetics—the study of heredity and variation of traits in a species.
2. Let each group discuss and then present their responses to the class.
 3. After all groups have presented their findings, ask trainees to read **2.1 Key Facts** in Trainee’s Manual. Ask a volunteer to read them aloud. Respond to any questions and provide additional examples as needed.



Guided Practice Activity

1. Ask trainees to read and follow the instructions for **Topic 2.1 Task 3** in their Trainee’s Manual. All trainees must write down an answer for each question, while working together.
2. Some people can roll their tongue and some people cannot. The ability to roll your tongue is an inherited characteristic. You inherit the ability (or lack of ability) from one of your parents. Can you roll your tongue? Have a try now. How many people in your class can roll their tongue?
3. Tell trainees to use their textbook or the internet to find out the meaning of the following key genetic terms: **chromosome, gene, allele, genotype, phenotype, homozygous, heterozygous, dominant allele, and recessive allele.**

Answers:

Approximately 4 of every 5 of the people in the class should be able to roll their tongues (generally it is 81% of the population).

Vocabulary:

- **gene:** a short length of DNA controlling an organism’s characteristics
- **allele:** the gametes that form genes
- **genotype:** the genetic make-up for a certain trait
- **phenotype:** the physical manifestation for a certain trait
- **homozygous:** a trait with both alleles the same – either both dominant or both recessive
- **heterozygous:** a trait with the two alleles different – one dominant and one recessive
- **dominant allele:** an allele carrying the trait which shows regardless of the other allele
- **recessive allele:** an allele carrying the trait which does not show if paired with a dominant allele

4. After all the groups have completed their research and have completed the definitions, have a large group discussion on common characteristics observed in people, noting that characteristics are either passed through inheritance from parent to offspring—or they are learned. An example is that we cannot change our height—but we can change our hair-style.
5. Chose a trainee to read the story related to Mendel’s experiment aloud. As the trainee reads the story, stop and discuss when you come to a question, and stop to provide a definition when you come to a word that is bold.

Topic 2.1 Task 4 : Case study

1. Tell trainees to read the following case study carefully and respond to the questions:

Gregor Mendel was born in 1822 in Austria. Growing up on his family’s farm, Mendel learned a lot about cultivating plants, flowers, and fruit trees. After completing his university studies, he entered the monastery. He worked in the monastery garden, where he was able to study how traits are passed from parents to offspring in plants.

Mendel studied only one characteristic at a time, such as the height of pea plants, flower color, or seed shape. Mendel watched carefully how traits changed or stayed the same when plants **self pollinated** (when both gametes come from the same plant) and also watched the traits carefully when plants were **cross pollinated** (when one gamete came from one plant and the other from a second plant with a different trait).

In his first experiment, Mendel cross pollinated plants that produce round seeds with plants that produce wrinkled seeds—those were the parent plants. The offspring from this cross were called “first generation” offspring and Mendel found that they were all round seeds.

- a. Do the results surprise you? (**Answers will vary**)
- b. What happened to the gene for the trait: wrinkled seeds? (**Answer:** it’s still there but hidden)

2. Tell trainees to continue reading:

Mendel proposed that a **gene** which regulates a given trait must have two parts, called **alleles**, one from each of the parent plants. Mendel proposed that in any pair of alleles, the **genotype** which is the type of alleles in the pair, would determine the **phenotype** which is the physical way that the trait looks on the organism. If the genotype of alleles is either both dominant or both recessive—that is, the pair is two of the same type of allele—then we call it **homozygous**. If the genotype is two different alleles, that is, one dominant and one recessive, then we call it **heterozygous**.

Mendel proposed that an allele could be strong, called a **dominant allele**, or weak called a **recessive allele**. If a dominant allele is present in the genotype—either both dominant alleles or one dominant allele and one recessive allele, then the dominant physical trait

(phenotype) would show. The recessive trait would ONLY show is when the genotype has both alleles as recessive alleles. The idea is that the trait of the dominant allele overpowers (or dominates) the trait of the weaker (recessive) allele.

Mendel, for his study, labelled the dominant gene as a capital letter and the recessive gene as a small letter. Then he used an organized grid to determine what allele pairs were possible in the offspring, that is the possible genotypes. Looking at the genotypes he could determine the possible phenotype for the offspring—that is, which trait (phenotype) would show. This grid is called a **Punnett Square**.

Here is what Mendel did when studying seeds which were either round or wrinkled: Because the round seeds occurred more often, he guessed that the round trait was the dominant allele. He labeled the alleles as follows: Dominant allele (round) and represented by **R** and recessive allele (wrinkled) represented by **r**.

First generation: To start, Mendel used only parent plants he knew were homozygous, that is the round carried two round (R) alleles and the wrinkled carried two wrinkled (r) alleles. Parent seeds were both homozygous. Parent genotypes were RR and rr.

When crossing the two parents (RR x rr) he wanted to know which types of offspring were possible. He designed a special grid. He put one parent genotype across the top and the other parent genotype down the left column, then filled in the grid as rows and columns crossed in each square to get genotypes for offspring.

Punnett Square first generation of round and wrinkled parent:

recessive alleles	dominant alleles	
	R	R
	r	r
R	Rr	Rr
r	Rr	Rr

We can see the possible genotype of offspring in the grey area of the grid.

All offspring have genotype Rr.

Because offspring all have one dominant gene (round R) their phenotype will all be round.

The one dominant allele determines the trait we see. All offspring have **heterozygous** genotypes— alleles are mixed, one dominant and one recessive.

Looking at offspring genotype, the ONLY possibility is Rr, that is 4:4 have Rr, or Rr= 100%.

From the genotype we can determine the **phenotype** (which physical trait shows) by noting if a dominant R is present or not. If R is present then the seed will be round. If not, if the only allele present is recessive r then the seed will be wrinkled.

The next step of the experiment was that Mendel planted the offspring to make a second generation of offspring. This time he made plants self-pollinate, so all plants had genotype (Rr) and they crossed with themselves thus genotype (Rr). Both parents were Rr.

If we make a Punnett square, Rr x Rr we get the following:

Punnett Square Second generation:

2 nd parent alleles	1st parent alleles	
	R	r
R	RR	Rr
r	Rr	rr

From the Punnett square we see that offspring have three different **genotypes**: RR, Rr, and rr.

*RR shows only once so the genotype ratio for RR is 1:4 or 25%,

*Rr gene is in two squares so the genotype ratio for Rr is 2:4 or 50%,

*rr ratio is only in one square so the ratio for genotype rr is 1:4 or 25%.

When we look at **phenotype**, we know all genes which have one or two R alleles will be round seeds, that is: RR and Rr thus 3:4 or 75% of the seeds are round. The wrinkled seeds (genotype only rr) will have the ratio of 1:4 or 25%.

To confirm this, Mendel decided to count the number of each type of seed in the second generation. He obtained 8003 total seeds, 6002 round seeds and 2001 wrinkled seeds. Approximately 75% of the seeds were round and 25% of the seeds are wrinkled—which confirmed Mendel’s hypothesis.

Note: both the RR and the rr genotypes are **homozygous** (the pair is two of the same type of allele) so 50% of the offspring are homozygous genotypes.

After doing his experiments, Mendel formulated his first law, the **Law of Segregation** stating:

Characteristics of organisms are controlled by genes; each gene is made up of a pair of alleles. During the formation of reproductive cells (gametes) in parents, the pair of alleles splits apart, and thus a parent gives only one allele to each offspring. Offspring receive one allele from each parent.

3. This is a tricky concept! The trainer must explain carefully. Use other examples so the trainees can practice making and interpreting Punnett squares both in pairs and individually. The following task is designed to provide practice for the trainees to make and interpret Punnett Squares. The trainees should work in pairs as trainer walks around class to help.

Topic 2.1 Task 5: Practice with Punnett Squares

- a. The following Punnett square shows a cross pollination between a homozygous plant resistant to drought (dd) and a heterozygous plant that is NOT resistant to drought. Review the square then answer the questions given:

2 nd parent alleles	1st parent alleles	
		d
	D	Dd
	d	dd

- How do we know that the second parent has the genotype Dd?
- Which is the dominant trait—resistant to drought or NOT resistant to drought?
- These plants produce 20 seeds (offspring). How many are resistant to drought?

Answers:

- We know the genotype because we are told it is heterozygous so it has one dominant allele and one recessive allele or Dd.
 - NOT resistant to drought must be dominant, if not then or both plants would show resistant to drought in their phenotype.
 - The plants produce 20 seeds so half (10 seeds) will be resistant to drought (genotype dd).
- b. There is a new strain of maize that has bigger cobs than usual, but the allele that produces bigger cobs is a recessive gene. If you have two parent plants that both produce small cobs, is it possible that a cross fertilization will produce bigger cobs? Explain using a Punnett square and explanations.

Answer:

Yes, it is possible. Both parents must be heterozygous—that is carry a dominant and a recessive allele.

Let C be small cob (dominant allele) and c be big cob (recessive gene) we get the following Punnett square:

2 nd parent alleles	1st parent alleles	
		C
	C	CC
	c	Cc

This Punnett square shows that if we produce 4 seeds, we should have one seed that produces big sized cobs—because the genotype we want is cc which has a genotype ratio of 1:4 or 25%. If both parents are heterozygous then there is a 25% chance a seed displays the recessive trait.

- c. There is a type of tomato plant that has two varieties: one ripens in 6 weeks the other ripens in 9 weeks. The farmers prefer the variety that ripens in 6 weeks so they can plant new crops after the tomato plant is finished. They have learned that the quick ripening tomato has the dominant gene. Is there a way to ensure that all seeds from one generation will ripen quickly? Draw a Punnett square to prove your answer.

Answer: YES! If the parents are both homozygous, one dominant the other recessive, then the next generation will ALL be heterozygous but their phenotype will be quick ripening.

2 nd parent alleles	1st parent alleles	
	t	t
	Tt	Tt
T	Tt	Tt
	Tt	Tt

5. Ask a volunteer to read **2.2 Key Facts** aloud then provide additional examples and respond to questions from the trainees.



Application Activity

1. Ask trainees to carefully read **Topic 2.1 Task 6** in their manual then answer the questions individually. When all trainees have finished, discuss the answers as a class:

Topic 2.1 Task 6: Mendel, another experiment.

Gregor Mendel carried out other experiments with pea plants. In one experiment he studied how the height of the pea plant was inherited. He took **homozygous** tall plants and crossed them with **homozygous** dwarf plants—so he knew that all his parent plants were carried only one kind of allele—they had either both dominant alleles or both recessive alleles.

Mendel cross pollinated those plants to produce the first generation. All the first generation plants were tall. Mendel self-pollinated plants from the first generation offspring to get second generation plants. In the second generation, the three-quarters of the plants were tall, and one-quarter were dwarf.

- Use Punnett squares to represent both the first generation and the second generation plants.
- If Mendel planted 100 seeds to grow the second generation, how many could he expect to be dwarf sized plants?

Answers:

- Punnett squares will be similar to the ones created in task 4.
- We can expect that 25 plants will be dwarf sized (25% of the total number of plants)

2. Discuss with the class the following three questions:

- a. Considering cross pollination in plants, how could a farmer improve their species?
- b. What strategies do farmers use to maintain needed characteristics in their farming?
- c. Have you observed any of these sorts of pollination in your experiences with farming?

Possible Answer:

- a. Farmers make an effort to cross pollinate with good characteristics thus reproducing offspring with good characteristics—or self-pollinate species which have good traits.
- b. Farmers are careful about which species reproduce, so they should ensure that species with bad traits do not reproduce or cross pollinate.
- c. Answers will vary.



Points to Remember

- Cross pollination (or cross breeding) can change characteristics.
- Self-pollination is when a plant produces both gametes for a next generation.
- Careful pollination (or breeding) can lead to keeping or expanding good traits.



Formative Assessment

1. Complete these sentences by choosing the correct word from inside the brackets:
 - a. Pea plants whose (genotype/phenotype) is tall may have the (genotype/phenotype) TT or Tt.
 - b. A tall pea plant with genotype TT is (homozygous/heterozygous) dominant.
 - c. A tall pea with genotype Tt is (homozygous/heterozygous) dominant.
 - d. A dwarf pea plant with genotype tt is (homozygous/heterozygous) recessive.
2. Match the words in the left-hand column with the definitions in the right-hand column.

Words	Definitions
1. Gene	a. Having two identical genes for a particular characteristic.
2. Alleles	b. The outward appearance of a trait in an organism.
3. Phenotype	c. Having two different genes for a particular characteristic.
4. Genotype	d. The pairs of gametes that form genes.
5. Homozygous	e. A short length of DNA controlling an organism's traits.
6. Heterozygous	f. The allele that only has an effect when homozygous.
7. Dominant	g. The allele that has an effect in both homozygous and heterozygous genotypes.
8. Recessive	h. A contrasting form of the gene for the same characteristic.

3. In pea plants, the allele for pink flowers (P) is dominant over the allele for white flowers (p). Using a Punnett Square:
- Determine the genotype of offspring of a cross between a pink flowered heterozygous plant and white flowered plant.
 - State the genotypic and phenotypic ratios and percentages.
 - If you have 100 flowers, how many would you expect to be pink?

Answers:

- a. phenotype, genotype, b. homozygous, c. heterozygous, d. homozygous
- 1-e, 2-d, 3-b, 4-h, v-a , 6-c , 7-g, 8-f
-

a.

2 nd parent alleles	1st parent alleles		
		P	p
	p	PP	pp
	p	Pp	pp

- Phenotype: pink= 50% or 2:4 white = 50% or 2:4
Genotype: PP= 25% or 1:4 Pp = 25 % or 1:4 pp = 50% or 2:4
- 50% of the flowers should be pink. That is, 50 of the 100 flowers will be pink.

Learning Outcome 2.2: Applying hybridization techniques to plants.

	Objectives: By the end of the learning outcome, trainees will be able to: a. Explain hybridization in plants b. Describe general techniques of hybridization in plants c. Discuss advantages of hybridization
	Time Required: 8 hours
	Learning Methodology: Small group work, presentation, large group discussion, brainstorm, and field trip.
	Preparation: ☐ Preparation of site for field visit at workplace. ☐ OR Selection of appropriate video demonstrating how hybridization is done in plants.
	Cross Cutting Issues: ✓ Gender: While forming small groups consider gender ✓ Inclusiveness: while selecting area for field trip ✓ Standardization culture: while selecting appropriate species
	Prerequisites: ▶ Basic knowledge of farming and animal husbandry. ▶ Basic knowledge of parts of flowering plants.

Key Competencies:

Knowledge	Skills	Attitudes
1. Define hybridization	1. Outline advantages of hybridization process	1. Curious
2. Explain use of Punnett squares in hybridization	2. Describe techniques of hybridization in plants	2. Persistent



Steps:



Getting Started: What do we know and where are we going?

1. Ask trainees to read the passage for **Topic 2.2 Task 1** in the Trainee's Manual. When everyone has read the passage independently, then trainees form groups of 4 and respond to the questions. After 5 minutes, brainstorm all answers as a class and write on the board.

Topic 2.2 Task 1: Read the passage below and answer the question

People in Rwanda have been farming the land for a long time. Many people grow tomatoes which are eaten both raw and cooked. Many people also grow cassava, from which people eat both the leaves and the roots. Two situations may occur: first, a farmer may find a plant that provides desirable characteristics, so the farmer will try to have more plants of that same type, or, a farmer may find two plants and each of the two may have one characteristic that is desirable so the farmer would like a mix of those two plants.

We learned in **Topic 2.1** about cross-pollination and self-pollination. In self-pollination, a plant produces offspring with the same characteristics as the parent—since both alleles come from one plant. When alleles come from two different plants, this is cross pollination. If cross pollination is done carefully, parent plants are chosen each with a different, desirable trait so the offspring may be a new plant that carries both good characteristics (one from each parent). This is called hybridization.

In this task, you and your peers will consider what good traits a farmer may look for, and then how to improve the crop of each of those vegetables through self- and cross-pollination.

- a. Brainstorm, in your group, characteristics that are most desirable in each of the following plants. Try to get as many responses as possible:
 - What are desirable characteristics of tomato plants?
 - What are desirable characteristics of a cassava plants?

- b. Think about cross-pollination. Pick two characteristics for each vegetable and explain what the advantage of cross pollination for the farmer may be.

Possible answers may include:

- a. **Tomato:** many fruits, big sized fruit, drought resistant plants, bug resistant plants, ...
Cassava: many leaves, dark green leaves, big root, quick growth, bug or fungus resistant
 - b. **Tomato:** if the farmer cross pollinates a plant that gives many fruits and is also drought resistant then the farmer will have bigger crops (many tomatoes) even during drought.
Cassava: if a farmer cross pollinates plants that grow quickly and have many leaves then the farmer will get sauce materials early and can also re-plant the sticks quite soon.
2. Explain to trainees that this is called hybridization. It is when good traits are chosen in two plants and then purposefully cross-pollinated to get the two good traits in a single new plant.
 3. Introduce the learning outcome and the type of knowledge, skills and attitudes they will gain from the learning outcome. Explain that this learning outcome will focus on how to apply hybridization techniques to plants.



Problem Solving Activity

1. Ask trainees to read the passage about a farmer's crossing experiment and do the related activity in groups of 3 trainees.

Topic 2.2 Task 2

Read the scenario on a farmer's crossing experiment and answer the questions that follow.

A farmer has crossed pea plants that have yellow grains with pea plants that have green grains. The pea plants with yellow grains reach maturity in 70 days, and each plant produces 600g of grains. Pea plants with green grains reach maturity in 60 days and produce 500g of grains, but they are resistant to drought.

Questions:

- a. Which original pea plant is better?
- b. If the farmer cross pollinates, what are traits that an offspring may carry?
- c. Note that some of the characteristics may be better and others worse. Why is this still a good idea?
- d. Are there options –other than cross pollination—that may be good options for the farmer?

Answers:

- a. Both of the plants have advantages and disadvantages—one produces more, the other matures faster. One is drought resistant. The choice of ‘better’ depends on environment as well as other farmer needs so the farmer needs to know which advantage is most important in the particular situation of that specific farm. Both have positive traits.
- b. A cross pollinated, hybrid plant may have the following characteristics: either yellow or green grains, maturity will likely be 65 days (a mix of the two), it may produce approximately 550g of grains, and may be drought resistant (depending if that trait is recessive or not).
- c. Although the production is not quite as much as yellow alone, the hybrid is drought resistant so it is safer to plant in case there may be a drought. One never knows.
- d. Another option is that the farmer could plant half of one grain and half of the other. In the case of a drought he will lose—but in the case of good rains he will gain.

Also, as we know from Punnett squares, not all offspring will carry expected traits, so that is a risk of hybridization.

2. Guide and follow group discussions while trainees are working.
3. If possible, invite a farmer or agricultural extension agent with experience using hybridization techniques to attend, explain, and provide added details.
4. Refer trainees to **2.3 Key Facts** in Trainee’s Manual for further information and vocabulary.



Guided Practice Activity

1. In pairs, let the trainees make visual representations of the experiment described in the scenario in **Topic 2.2 Task 2**. Guide and verify each pair’s answer. Select 3 pairs to present their findings.

Topic 2.2 Task 3:

Re-read the scenario on the hybridization experiment done by the farmer in Task 2. Sketch a visual representation (illustration or diagram) of the experiment showing the parent plants (with different traits) and then the offspring with their new traits.

- Share your drawing with peers. (**Answer:** Drawings will vary but in cross pollination, the good traits from each plant will then be found in one plant.)
 - Discuss the value of hybridizing plants with the class. (See **Answer a** above as well as information on cross pollination in **Topic 2.2 Task 1**.)
2. After 3 pairs have presented their visual representations, have a large group discussion on purpose of hybridizing plants.

3. When trainees have a sound understanding of hybridization including reasons to use it and a general idea of the processes use, explain that you will now see the process in action. If possible visit a farm where hybridization is happening. If this is not possible then trainer should find a video on line that shows the process in detail which can be shown to the trainees in class. A visit to an actual farm is much preferred as it is more relevant to the lives of the trainees and because trainees can then interact with the farmer to get a deeper understanding of the process.

Topic 2.2 Task 4: Group activity on watching movies /field visit to farmer hybridizing plants

1. Either visit a farm doing hybridization (this is the preference) or find a video showing hybridization and let the students watch that video.
2. Explain that during the visit (or video) the trainees should be thinking about the following questions which the entire class will discuss after the visit (or video).
3. Guiding Questions:
 - a. Pay close attention to the process used. As much as possible write down each step in the process of hybridization and then explain why each of the steps is important.
 - b. What does the farmer (or video) tell you about the need for hybridization in that specific situation?
 - c. Using one plant as an example, describe an advantage of hybridization—as well as some potential negative consequences.
4. Upon return to the classroom, or after completion of the video, ask for volunteers to present their findings/responses to the guiding questions. Let these presentations be the foundation for a large group discussion on the hybridization in plants.



Application Activity

1. Ask trainees to read and perform the **Topic 2.2 Task 5** in their manuals in pairs.

Topic 2.2 Task 5: Improving seed quality

In maize, the gene for starchy seeds is dominant over that of sugary seeds. Two homozygous plants were crossed, one starchy, the other sugary.

- a. What is the genotype and phenotype of the first generation seeds, both parents?
- b. When these offspring seeds grew into mature plants, they were allowed to cross pollinate. The seeds from this group are now the second generation of seeds: What is the expected ratio of starchy to sugary seeds in the second generation the plants offspring?
- c. If this was the practice of a farmer, what was his purpose?
- d. Describe how the farmer has crossed the two plants? Provide clear identification of the steps followed and a short explanation for each.

Answers:

- a. The genotypes are SS and ss, the phenotypes are SS=starchy and ss=sugary
- b. The first generation seeds will all have Ss genotypes:

	s	s
S	Ss	Ss
S	Ss	Ss

So the second generation will come from two parents both with Ss genotypes so the Punnett square will be the following:

	S	s
S	SS	Ss
s	Ss	ss

From this Punnett square we see that among the four possible offspring only one (ss) will have the phenotype of sugary seeds, and the other three will have starchy phenotype so the ratio will be starchy to sugary of 3:1.

- c. If the farmer did these crosses on purpose, the farmer must have wanted to keep both starchy and sweet seeds. If he had wanted only sweet seeds, he would have pollinated only the homozygous sweet seeds together... and there may be other traits that the farmer was trying to amplify—maybe the heterogeneous seeds are more drought or bug resistant, for example.
- d. The steps that the farmer would follow are the following:
 - 1. Identify the parent plants that are homozygous and isolate some of their flowers.
 - 2. Cross pollinate the flowers from the two homozygous plants then bag the flowers to avoid further pollination with random other flowers.
 - 3. Gather seeds from the bagged flowers and re-plant.
 - 4. Isolate some flowers on the 1st generation offspring plants for pollination.
 - 5. Do the pollination then bag the flowers.
 - 6. Collect the seeds from the 2nd generation plants that were pollinated by the farmer.
- 2. Ask trainees to look for people at home or in the workplace working with seeds. Ask these people politely about the processes they use:
 - a. Where do the seeds come from?
 - b. How do people care for their seeds—storing them? Labelling them? Etc.
 - c. Do people have ideas about how to improve (or maintain) the quality of their seeds?
 - d. Have these people purposefully gathered seeds from plants that were strong/better/higher quality—and if so, what do they do with those seeds?

- e. Does anyone have experience with hybridization?



Points to Remember

- **Hybridization** can amplify specific traits in offspring—but it is a slow, complex process with possible negative side effects like offspring being sterile.
- **Selective breeding** is like hybridization, but it is done by selecting animals with specific good traits (both males and females) to breed and produce offspring together. Examples might be:
 - cows that produce lots of milk
 - chickens that produce large eggs
 - wheat plants that produce lots of grain



Formative Assessment

1. If **R** represents the dominant red coat colour in cattle, and **r** represents the recessive white colour, which is the correct description of the genotype **RR**?
 - a. Heterozygous
 - b. Heterozygous dominant
 - c. Homozygous dominant
 - d. Homozygous recessive
2. Pea plants can produce yellow seeds or green seeds. Yellow colour is dominant over green colour. We use the letter “**C**” to represent colour of the allele for yellow seed colour and “**c**” for recessive green seeds.

Write the correct genotype for each plant listed below.

 - a. A homozygous dominant plant.
 - b. A homozygous recessive plant.
 - c. A plant that produces green seeds.
3. Brown eye colour is dominant over blue eye colour. The letter “**B**” is used to represent the allele for brown eyes and “**b**” for the allele for blue eyes.
 - a. What is the phenotype of a person who has the genotype **Bb**?
 - b. What is the genotype of a person who has blue eyes?
 - c. What is the genotype and phenotype of a person who is homozygous dominant for eye colour?
4. A farmer has many sunflower plants but has found two plants that are especially good. One plant gives many seeds and another plant ripens quickly. Write a few sentences to help the farmer learn how to hybridize those two plants so the next generation plants might have both the desirable traits.

Answers:

1. C

2.

- a.** CC
- b.** cc
- c.** cc

3.

- a.** Brown eyes
- b.** bb
- c.** BB - brown eyes

4. The farmer has already chosen the good plants. He should manually cross pollinate the two plants and then bag the flowers as the seeds develop so other random fertilization doesn't happen with other sunflowers. When the seeds ripen the farmer should gather those bagged seeds and store them separate from the other seeds collected so he knows that those should be re-planted (not eaten or made into oil).

Learning Outcome 2.3: Applying hybridization techniques to animals

	Objectives: By the end of the learning outcome, trainees will be able to: - Explain why gender determination depends on the chromosome from the male parent - Identify gender and correct chromosome pairs in karyotypes - Describe good traits in farm animals and explain how to breed animals in a way to keep or enhance those traits
	Time Required: 7 hours
	Learning Methodology: Small group work, presentation, large group discussion, brainstorm and research.
	Materials Needed: - Different pictures of karyotypes - Flipcharts and markers
	Preparation: ☐ Write the story/scenarios/questions on flipchart so all can see or make copies for each small group.
	Cross Cutting Issues: ✓ Gender: While forming small groups consider gender ✓ Inclusiveness: while selecting area for field trip. ✓ Standardization culture: while selecting appropriate species. ✓ Environment and sustainability: while preparing field trip.
	Prerequisites: ▶ cells ▶ chromosomes

Key Competencies:

Knowledge	Skills	Attitudes
1. Explain inheritance	1. Demonstrate gender inheritance using karyotypes	1. Attentive to detail
2. Identify inheritance of gender in humans	2. Describe how good traits might be carried to the next generation among farm animals	2. Persistent



Getting Started: What do we know and where are we going?

1. Read aloud the proverb to the class:

“The apple never falls far from the tree!”

2. Ask trainees to think about what this means (in terms of inheritance), and respond to the questions in their manual, **Topic 2.3 Task 1**.
 - a. How does this proverb relate to inheritance of traits from parents to offspring?
 - b. Can you think of any other proverbs that may relate to inheritance too?
 - c. List three traits that you share with your mother and three different traits that you share with you father. Put a star next to the traits that you share with your siblings—are there any traits that you alone share with your parents?

Answers:

- a. The idea is that apple are the offspring, and they are always ‘near’ or like their parent, the apple tree...that is, children are like their parents...another way to put this might be to say: like father, like son! (or, like father, like daughter, or, like mother like daughter or like mother like son) ... knowing that children inherit characteristics from parents.
 - b. Like father like son...others?
 - c. Answers vary.
3. When trainees have completed their tasks independently, let some share responses.
 4. Introduce the learning outcome with the knowledge, skills and attitudes trainees will gain from the learning outcome. Explain that this learning outcome will focus on inheritance and chromosomes in humans.



Problem Solving Activity

1. Put trainees in small groups and ask them to read the article about human being resemblance in **Topic 2.3 Task 2**. After they have read the article independently, trainees should pair up and answer the related questions with a partner.

Topic 2.3 Task 2: Investigating inheritance humans

All human beings bear a basic resemblance to one another because of their shared human heredity. People, however, differ greatly on an individual level. Features such as height, and the colour of eyes, hair, and skin are immediately visible to an observer. If you look more closely you will notice finer differences in the shapes of facial features, the lengths of hands and feet, skin details, etc. There are also hereditary traits that are not visible on a human's outside, but are found within their bodies, for example blood type, color-blindness, diseases such as cancer or other conditions.

Because siblings inherit different combinations of traits from their shared parents, brothers and sisters who have the same parents may still differ in many ways. The combinations of the traits one inherits is different than the combination of traits inherited by the other siblings (except in identical twins). Variations in traits are because the parental genes combine in different ways for each offspring, even among families, as traits are passed from generation to generation.

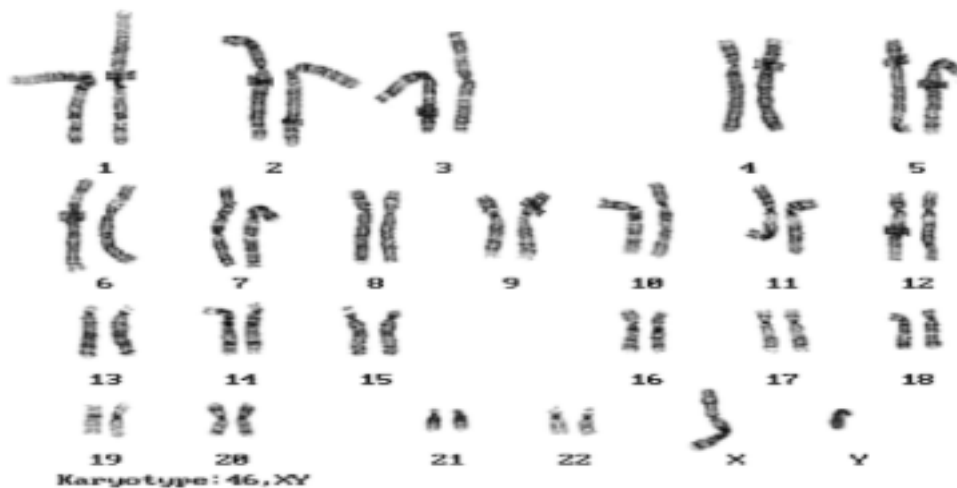
Inherited genes are found on a structure called chromosomes within the DNA inside all cells. Humans have 23 pairs of chromosomes (that is 46 total chromosomes, 23 from the mother which pair with 23 from the father). Scientists have been able to separate the 23 pairs of chromosomes and take a microscope photograph (called karyotypes) of sets of human chromosomes. See the examples below. Each pair of chromosomes controls different traits or conditions, the very last pair, the 23rd pair, controls the gender of the offspring.

Scientists have determined that gender is determined by the 23rd pair of chromosomes. The two possible chromosomes in that pair are labeled X or Y. You can see in the karyotypes below that the X chromosome can be identified because it is longer than the Y chromosome. A female has two X chromosomes (genotype: XX) and a male has one X chromosome and one Y chromosome (genotype: XY). The female is homozygous—that is, she has ONLY X chromosomes, so when she has an offspring, she can only provide an X to the next generation. The male parent is heterozygous, that is, he has an X and a Y

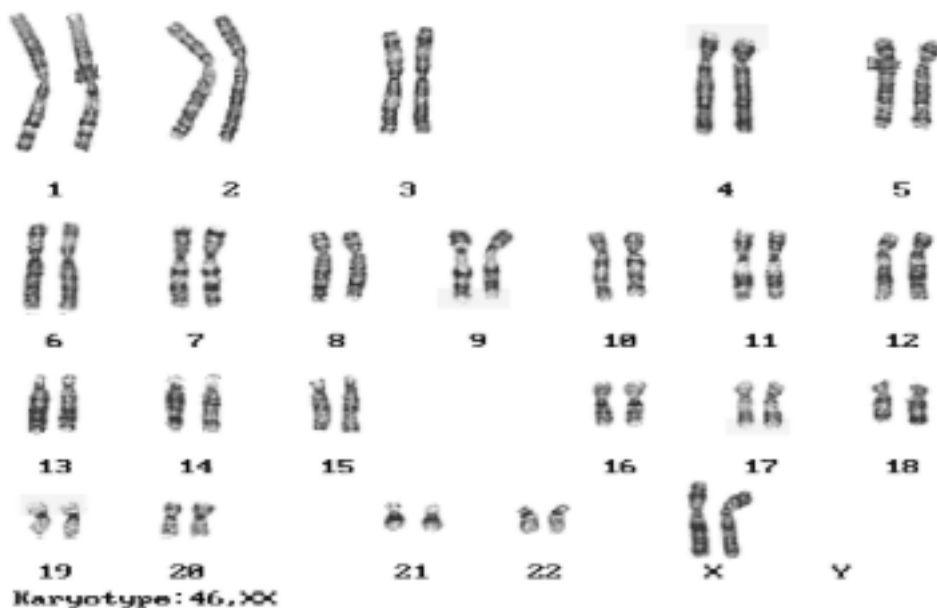
chromosome so when he has an offspring, he may provide either an X or a Y to the offspring. Given this, the determination of gender of an offspring depends solely on the chromosome given to the offspring by the male parent; an offspring always gets an X from the mother and could get X or Y from the father—which thus determines gender of the offspring. If the father gives an X the offspring will be a girl. If the father gives a Y the offspring will be a boy.

Below are examples of karyotypes of human chromosomes. Take note that all the 23 pairs of chromosomes are in place, and note the 23rd pair where you can identify the gender.

The following is a karyotype of a male, because there is a Y chromosome:



Compare the above karyotype to the following karyotype. This karyotype shows two X, and no Y chromosomes. The 23rd pair identify the following karyotype as coming from a female.



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- List out 10 traits that are inherited from our parents.
- Explain how gender is “inherited” from our parents, and explain which parent is responsible for the gender determination of offspring.
- Notice that the two karyotypes above look different: write three ways that the chromosomes in the karyotypes are similar and three ways that they are different.

Answer:

- Answers vary.
- Gender is inherited from our parents because X and Y chromosomes are passed to offspring. The female parent has genotype XX so she can pass only an X chromosome. A male parent has both X and Y so he may pass one or the other – thus the gender of an offspring is determined only by the chromosome the father gives to the offspring.
- The two karyotypes are similar: both have 23 pairs, in both the paired chromosomes are slightly different shapes, both have curved and straight chromosomes, etc.

The two karyotypes are different: one is male the other is female (no Y chromosome), one has more curly chromosomes, one is darker than the other, etc.

- Let several trainees share their answers, ensuring that the idea that gender is determined by the chromosomes we inherit is clear, and that it is clear that the male parent is the person that determines the gender of the offspring. Ensure that trainees have understood the details of a karyotype, and how to identify gender by looking at a karyotype.

¹⁴ Images from: Indiana University–Purdue University Indianapolis.
(n.d.). *Karyotypes*. <https://www.biology.iupui.edu/biocourses/N100/2k2humancsomaldisorders>

3. Choose a volunteer to read aloud **2.4 Key Facts**. Ask trainees which terms they have seen for the first time. Discuss each term in detail, encouraging trainees to give examples based on real life situations so they can all see how this topic relates to their lives.



Guided Practice Activity

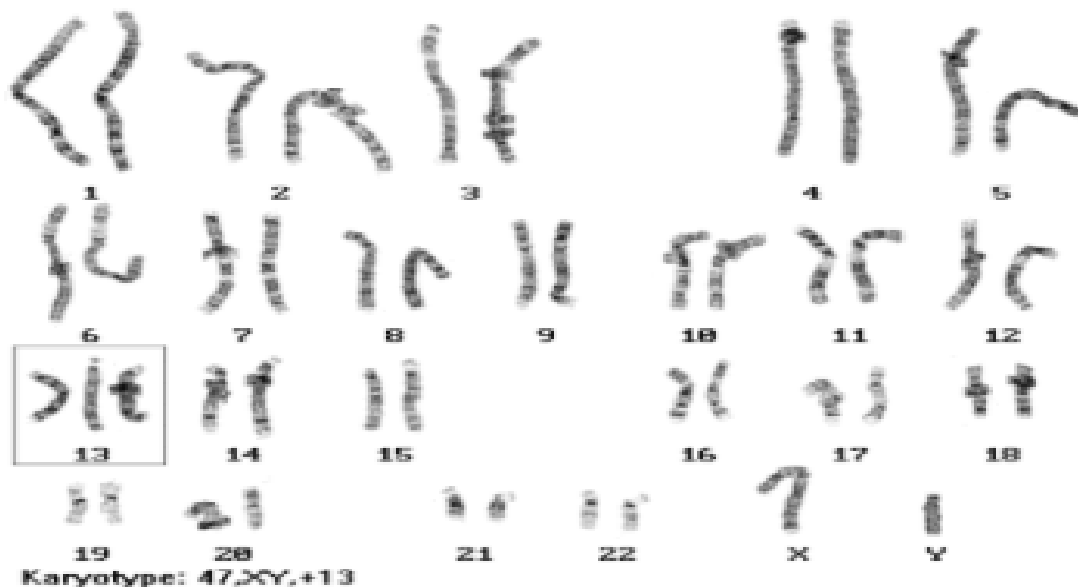
1. Ask trainees to look at the first karyotype (a.) in **Topic 2.3 Task 3**. Take 2 minutes to allow each trainee to observe and consider the karyotype. When they have had time to think about it individually, you, as the trainer will model how you begin to analyse a karyotype.



2. Note aloud the following: When looking at a Karyotype there are three quick steps:
- Count the pairs of chromosomes to confirm there are 23 pairs.
 - Determine the gender of the human by examining the 23rd pair - XX or XY? Female/Male?
 - Examine each pair to ensure that there are 2 chromosomes in each place there should be a pair.

Answer: This is a female (two x chromosomes), she has complete pairs for all 23 chromosomes.

3. Ask trainees, with a partner, to examine the second (b.) karyotype in their manuals. Based on what you modelled for the first karyotype, ask them to give the gender and any other relevant information about the person to whom the chromosomes belong.



Answer: This is a male. While most of his other chromosome pairs are in place, he has an extra chromosome on the 13th pair, so this person has a chromosome problem.

4. Use the above two examples of karyotypes to explain to the class that very rarely things are not the norm at the level of chromosomes and sometimes people may have an extra chromosome (or sometimes a missing chromosome). This may cause a disease or a physical condition or it may not matter for the life of the person, depending on what chromosome is extra or missing. One example of this is that people with the above shown extra chromosome have what is called Down Syndrome, a rare condition but one that happens in a certain (small) percentage of the population.
5. Ask trainees to work independently as they examine the next karyotype in **Topic 2.3 Task 4**. After 3 minutes ask a trainee to explain their response. Validate their response and respond to any questions.

Topic 2.3 Task 4

Review the following karyotype. Give the gender and review all the pairs to identify any abnormalities.



Answer: This is a female. 22 of the pairs of chromosomes are normal, but one pair (the 21st pair) has an extra chromosome which may cause a condition or disease in this human.

6. Explain to the trainees that gender determination in most mammals, like in humans, is dependent on the chromosome that is given by the male parent to the offspring. It is also true that in most farm animals, various traits are inherited from parents. When farmers are considering mating their livestock, it is valuable to consider which parents, both male and female carry the traits that the farmer is looking for. Ask trainees to consider cattle. What are some desirable traits in cattle that a farmer might hope to find in the next generation of offspring at the farm? Together as a class brainstorm some traits that cows and bulls should have that are good for a farmer. Once you have completed a list on the board, ask trainees to think of how the farmer might ensure those good traits are passed along—or even made stronger—in next generations of farm animals.

Topic 2.3 Task 5: Brainstorm—what are desirable traits for cattle on a farm?

1. Brainstorm, together with the other trainees, a list of desirable traits for both cows and bulls on a farm.
2. Once you have a list of traits among cattle that are good for farmers, explain why each trait would help a farmer.
3. Finally, consider some ideas of how the farmer might ensure that the wanted traits are found (or even strengthened) in the next generation of the farm's cattle.

Answers:

1. Desirable traits may include produces lots of milk, grows quickly and has big muscles (thus lots of meat when butchered), is rarely sick, eats well, is not mean to humans, gives birth easily, etc.

2. Lots of milk and meat mean the farmer can make money from the cows, rarely sick and eats well means they are not troublesome to raise, is not mean means the farmer doesn't have to worry about the cow injuring the family or neighbours, etc.
3. To ensure the wanted traits are passed to next generations, the farmer must ensure that the animals with the good traits mate with other animals with the good traits—and that those animals with bad traits are not mated with others so the bad characteristics are not passed.
7. Explain to trainees that this is called selective breeding (refer to points to remember in previous learning outcome) and is important for farmers to consider when they breed their farm animals.

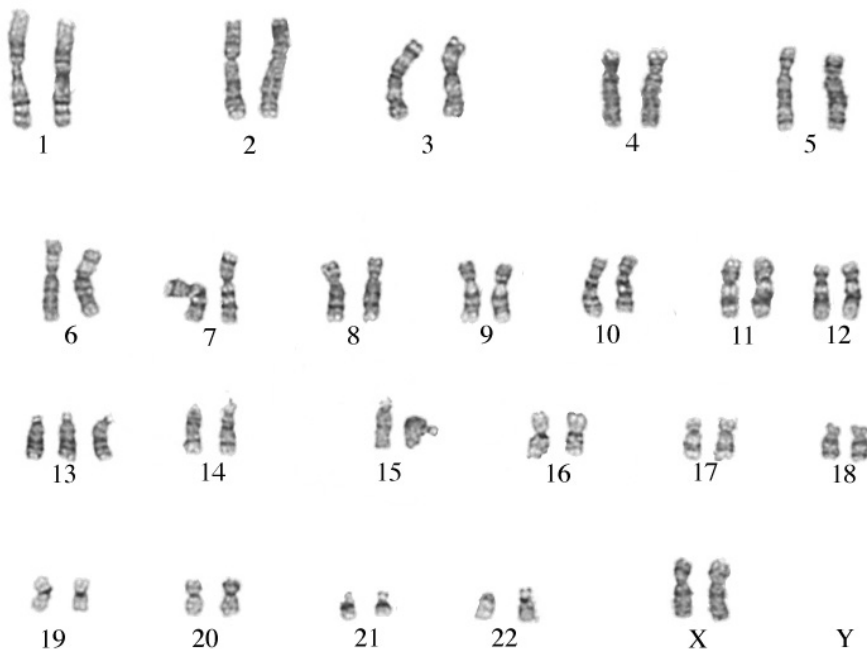


Application Activity

1. Ask trainees to work in pairs and to respond to **Topic 2.3 Tasks 6 and 7**. After the trainees have completed the exercises, ask for volunteers to share the work with their peers by presenting in front of the class.

Topic 2.3 Task 6

Review the following karyotypes. Determine the gender of the human to whom the chromosomes belong, and confirm that all 23 pairs are correctly in place.



Answer: This is a female. 22 of the pairs of chromosomes are normal, but one pair (the 13th pair) has an extra chromosome which may cause a condition or disease in this human.

2. Trainees should work in pairs to complete **Task 7**. Pairs should think of as many responses as possible for each part of the task. After about 5 minutes, ask some pairs to share their responses with the class.

Topic 2.3 Task 7

- a. Consider a farm that raises sheep. Make a list of desirable traits for sheep on a farm.
- b. Once you have a list of traits that are good for sheep on a farm, explain why each trait would be a benefit to the farmer.
- c. Finally, consider some ideas of how the farmer might ensure that the wanted traits are found (or even strengthened) in the next generation of sheep on this farm.

Answers:

- a. Desirable traits may include: produces lots of milk, grows quickly and has big muscles (thus lots of meat when butchered), produces soft wool which can be sold for yarn, is rarely sick, eats well, is not mean to humans, gives birth easily, etc.
- b. Lots of milk, meat, and wool mean the farmer can make money from the sheep, rarely sick and eats well means they are not troublesome to raise, is not mean means the farmer doesn't have to worry about the sheep hurting the family or neighbours, etc.
- c. To ensure good traits are passed to next generations of sheep, the farmer must ensure that the animals with the good traits mate with other animals with the good traits—and that those animals with bad traits are not allowed to reproduce (may be butchered earlier) so the bad characteristics are not passed to future generations of sheep on the farm.

3. Ask trainees to complete **Topic 2.3 Task 8** at home or after class:

Topic 2.3 Task 8

- a. Carry out internet or library research to find more pictures of karyotypes and try to identify the gender and to determine if all other chromosomes are correctly in place. If you have any questions, ask your trainer for guidance and support.
- b. Visit a farm near your home and ask the farmer if they consider the traits of the animals that they raise when they breed the animals. Discover what traits are considered desirable in various farm animals and determine if the farmer takes steps toward selective breeding to ensure that those with good traits are bred with others with good traits.

Answer: All will vary but should be verified by trainer.

4. Ask a trainee to read aloud Points to Remember. Discuss and respond to any questions.



Points to Remember

- Offspring carry many traits that are inherited from their mother, their father, or both, but some traits are learned or influenced by the environment.
- Gender is an inherited trait. The chromosome given by the father determines the gender of offspring. A mother always gives an X; A father gives either X or Y which determines gender. This is true in humans and in most mammals.
- Humans have 23 pairs of chromosomes inherited from parents. A picture of the chromosomes, called karyotypes, can identify gender and some chromosome abnormalities.
- Farmers that hope to keep or amplify certain traits among their animals should practice selective breeding to ensure animals with good traits mate with others with good traits.



Formative Assessment

- Choose words from the list below to complete the following sentences. Each word is used once:
recessive, dominant, karyotype, gender
 - The allele which has an effect in both homozygous and heterozygous conditions is called
 - A is a photograph of chromosomes from a human.
 - The allele that only has an effect when homozygous is called.....
 - The 23rd pair of chromosomes determines the in humans and most mammals.
- Review the following karyotype and answer the questions following:
-



- a. Is this human a male or a female? Explain how you know.
 - b. Do you notice any chromosomal abnormalities? If so, describe what you see.
4. Consider a farmer who raises pigs. Some pigs are mostly black in colour and are always healthy, a second group are mean and tend to be sick more often, and the third group of pigs have a lot of hair on their back and grow quickly. She is considering which pigs to butcher and which pigs to breed to raise another generation of pork.
- a. Which pigs would you consider the pigs with the worst qualities?
 - b. What would you advise about which pigs the farmer should butcher first?
 - c. Explain how the farmer might get a pig that is both healthy and grows quickly.

Answers:

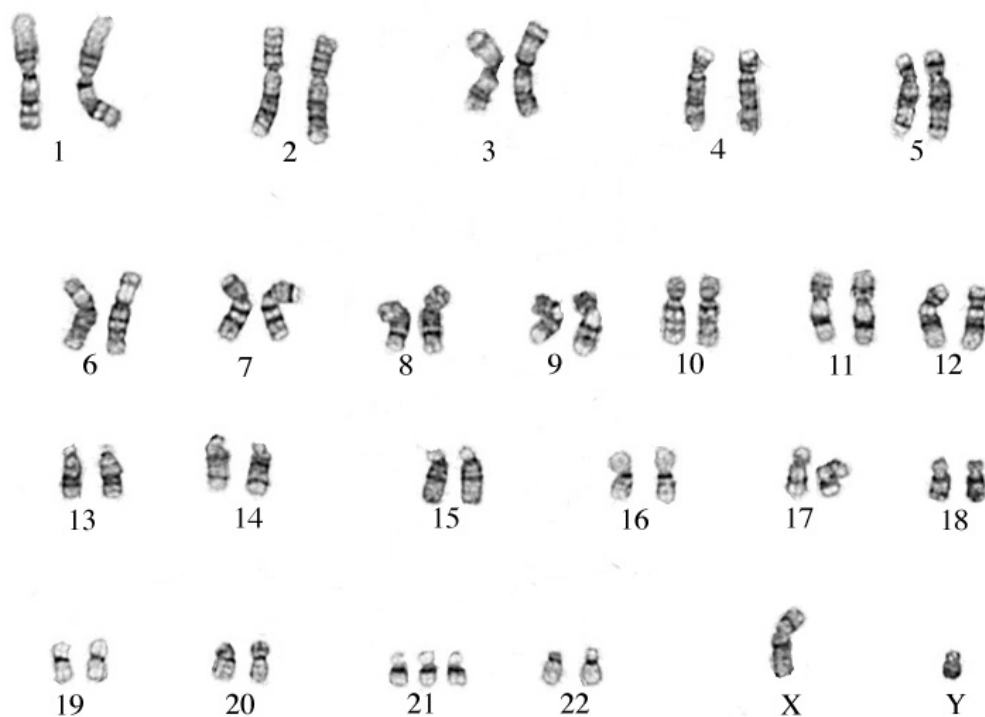
1.
 - a. Dominant
 - b. Karyotype
 - c. Recessive
 - d. Gender
2.
 - a. This is a male human because there is one X and one Y chromosome.
 - b. There are no abnormalities (all 23 pairs are complete with no extra chromosomes)/
3.
 - a. The second group of pigs (mean and often sick) are the pigs with bad qualities
 - b. The second group of pigs (mean and sick) should be butchered first
 - c. Both the first group (black and healthy) and the last group (hairy and grows quickly) are pigs with good qualities. The farmer could either breed the two groups together to try to get pigs that are healthy and grow quickly—or they could keep the groups breeding within the group so some pigs will always be healthy and others will grow quickly. Neither groups of pigs with good traits should be allowed to breed with the bad group.



Summative Assessment

1. Bagging is enclosing the flower in a suitable bag to prevent random cross-pollination. True or false?
2. Inheritance is the transmission of genetic information from one generation to another. True or false?
3. A family has a daughter. Explain which parent gave the chromosome that determined her gender, and how we know this.
4. Distinguish between the following pairs of terms, by giving good definitions of each.
 - a. genotype and phenotype

- b.** homozygous and heterozygous
- 5.** A homogeneous rooster with grey feathers was mated with a white hen. Grey feathers are dominant over white.
- Draw a Punnett Square to show the possible offspring that this mating could produce.
 - Write the phenotypic ratio for the cross.
 - Write the genotypic ratio for the cross.
 - If 10 offspring are produced, how many will likely be grey?
- 6.** A lab technician would like your help reviewing a karyotype below. Give gender and determine if all chromosomes are in place and normal:



- Is the karyotype normal? If not explain what you observe.
 - What is the gender of this human? Explain how you know.
- 7.** Using examples of maize plants, explain the steps you can follow to hybridize two plants, one that gives many seeds and one that is resistant to drought.
- 8.** Give an example of why a farmer should not breed his horse that pulls a cart very well with the horse of a neighbour if that other horse kicks people too often.

Answers:

1. True
2. True
3. Gender is determined by the chromosome given by the male parent. Because females have only X chromosomes, an offspring can only inherit an X from their mother. Males have both an X and a Y chromosome so an offspring might inherit either one. If the father gives the offspring an X, it will be female, if the father gives the offspring a Y, it will be a male.
4.
 - a. Genotype: genetic constitution of an individual, or the genetic makeup an organism which determine a trait.

Phenotype: is the characteristics of that individual, the observable characteristics determined by the genotype.
 - b. Homozygous is an individual having two identical alleles for a trait. While heterozygous is an individual in which the alleles are different.
5.
 - a. Punnett Square:
Let G represent grey feathers (dominant) and g represent white feathers (recessive)

	G	G
g	Gg	Gg
g	Gg	Gg
 - b. The phenotype ratio for the 1st generation is Grey: White 4:0, so 100% will be grey.
 - c. The genotype ratio is Gg 4:4 that is 100% will have genotype Gg.
 - d. If there are 10 off-spring we can expect ALL 10 to be grey.
6.
 - a. The karyotype shows that there is an abnormality on the 21st pair—there is an extra chromosome.
 - b. This karyotype is from a male because there is one X chromosome and one Y chromosome.
7. The farmer should choose two plants – one carrying the trait of many seeds, the other carrying the trait of drought-resistance. The farmer should purposefully cross pollinate those two plants and when the flowers are fully pollinated, the farmer should put bags around the flowers to eliminate the possibility of random natural pollination with other plants. When the seeds develop the farmer can remove the bag and harvest the seeds which should be stored separate from the other seeds and then planted in a place that is labelled carefully so the farmer can watch the hybrids grow and determine if the traits were passed along successfully.

8. A farmer should be careful about breeding his good horse with a bad horse. If those two breed, the farmer may get offspring that kick too much which is dangerous.



Self-Reflection

1. Ask learners to re-take the self-assessment found at the beginning of this unit. They should then fill in the table under self-reflection in the Trainee's Manual to identify their areas of strength, areas for improvement and actions to take towards improvement.
2. Discuss trainees' results with them. Identify any areas that are giving many trainees difficulties and plan to give additional support as needed (ex. use class time before you begin the next learning outcome to go through commonly identified difficult concepts).

Learning Unit 3: Chemistry - Atomic and Molecular Structure



Learning Outcomes

By the end of the learning unit on Chemistry, trainees will be able to:

- 3.1** Explain the difference between elements, compounds and mixtures
- 3.2** Explore periodic table according to the atomic structure of the elements
- 3.3** Apply knowledge of atomic structure to the formation of chemical bonds

Learning Unit 1 Self-Assessment

- 1.** Ask trainees to look at the illustration below and discuss what they see/observe. What topics do you think may be included based on the illustrations? After brainstorming, outline the main topics.
- 2.** Ask trainees to fill out the self-assessment at the beginning of the unit in their Trainee Manuals. Explain that the purpose of the self-assessment is to become familiar with the topics in the unit and for them to see what they know or do not know at the beginning. At the end of the unit, they will do a self- reflection, which includes re-taking the self- assessment and identifying their strengths, areas that need improvement and actions to take. The self-assessment is not a test!

Learning Outcome 3.1: Explain the difference between elements, compounds and mixtures

	Objectives: By the end of the learning outcome, trainees will be able to: - Investigate what all matter is made of – atoms and molecules - Recognize that all elements are found on the periodic table - Explain the difference between an element, compound and mixture
	Time Required: 7.5 hours
	Learning Methodology: small group work; practical work; pair work; brainstorming
	Materials Needed: - Each group of 4-5 trainees should have the following: - Problem Solving Activity: different dried beans/corn kernels/peanuts and small sticks (toothpicks); Cards with diagrams/drawings of atoms from an element, molecules made from one element, molecules made from 2 elements, mixture, compound - Guided Practice Activity: small cup of water, a tablespoon of salt, 3 tablespoons of flour, 1 tablespoon of sugar and a small amount (pinch) of yeast; small containers, spoons or other stirring implements; cup of water and teaspoon of salt - Application Activity: cup of muddy water mixed with small stones and sand, toothpicks/small sticks, old cloth torn into squares
	Preparation: ☐ Ensure you have all the required materials listed above ready and prepared. ☐ Make a set of 5 cards for each group (e.g. for 5 - 6 groups) with drawings of: Atoms of an element, Mixture, Molecule of an element, Compound, Molecule of 2 elements. ☐ Prepare a bucket of muddy water, small stones and sands before class for the application activity.
	Cross Cutting Issues ✓ Gender and inclusivity: Ensure groups where possible are mixed female and male. Mix different ages of students where possible. Encourage equal representation of male/female/young/older trainees to answer questions, present results and to be engaged in all activities.
	Prerequisites: ▶ None

Key Competencies:

Knowledge	Skills	Attitudes
1. Recognise that an atom is the smallest building block	1. Examine the size of atoms in relation to grains of sand/salt	1. Pay attention to details
2. Describe why only elements are found in the Periodic Table	2. List some elements from the Periodic Table	2. Develop curiosity about uses of some common elements
3. Define an element, compound and mixture in simple terms	3. Classify different substances as elements, compounds and mixtures	3. Develop curiosity about uses of common compounds and mixtures calculations



Steps:



Getting Started: What do we know and where are we going?

1. Refer trainees to **Topic 3.1 Task 1** in their manuals. Ask trainees: Think about your body. What are the smallest parts that it is made up of?
Possible answers: include muscles, blood, bones, nails, a hair
2. Ask trainees: Think about this smallest part and what it is made up of e.g. what is blood made up of?
Possible answers – cells, red parts, plasma
3. Ask trainees: What are these cells made up of? If trainees do not know, do not ask any further. Can you see these smallest parts?
4. Explain to trainees: Everything can be broken down into smaller and smaller parts. These small building blocks are so small that we cannot even see them; even if we used a magnifying glass or standard microscope, we would not see them.
5. Ask trainees: Does anyone know the name of these smallest building blocks?
Answer: atoms and they CANNOT be broken down into anything smaller.
6. Say: Each trainee should work with one other. Take a small amount of salt; try to separate out one grain of salt from the pile!
7. Ask trainees: How many atoms do you think there are in this one grain of salt?

8. Explain: Scientists have calculated that one grain of salt contains 10 quadrillion atoms - that is 10,000,000,000,000,000.
9. Explain: This learning outcome will look at what everything is made up of, how scientists have placed all substances that cannot be broken down into any other substance in a grid called the Periodic Table and the difference between these elements and other substances called mixtures and compounds.



Problem Solving Activity

1. Before class, have the following prepared: 1) different dried beans/corn kernels/peanuts and small sticks (toothpicks) for Steps 4-6. 2) A set of 5 cards for each group for Step 8, with the following representations drawn on the cards: Atoms of an element, Mixture, Molecule of an element, Compound, Molecule of 2 elements.
2. Ask trainees to look at the different diagrams in **Topic 3.1 Task 2** (and below) of different substances made up of atoms and answer the questions that follow:

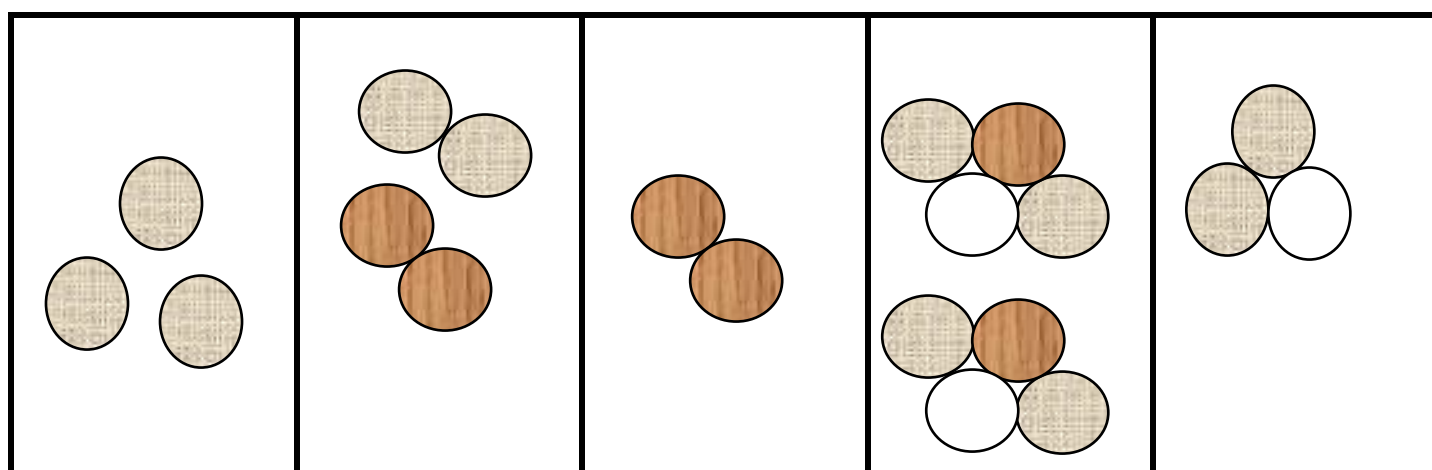
Substance A	Substance B	Substance C

- a. How many types of atom is Substance A made up of? **Answer:** 1 type of atom
- b. How many types of atom is substance B made up of? **Answer:** 2 types of atom
- c. How many types of atom is substance C made up of? **Answer:** 2 types of atom
- d. What is the difference between Substance B and C? **Answer:** substance C – the atoms are joined together in groups of 3; 2 grey atoms and a white atom; in Substance B, it is only the grey atoms which are joined together in groups of 2 and the white atoms are not joined to anything. When atoms are joined together, this is called a **MOLECULE**. Molecules can be atoms of the same element joined together (Substance A) or atoms of different elements joined together (Substance C).

3. Explain to trainees: substance A is made up of only one type of atom. This means that it is called an **ELEMENT**. If there are 2 or more different types of atoms joined together (Substance C), this is called a **COMPOUND**. If there are 2 or more types of atoms present but these are NOT all joined together (Substance B) this is called a **MIXTURE**.
4. Ask trainees to sit in groups of 4-5 and turn to **Topic 3.1 Task 3**. Give each group 3-4 different types of seeds e.g. corn kernels, peanuts, any dried beans, coffee beans and very small sticks/toothpicks. Each group should receive a handful of each seed/kernels. Tell groups that the seeds/kernels represent different types of atoms and that the sticks can be used to show atoms bonded together; for example, in a molecule.
5. Ask each group to use their seeds/kernels and sticks (where needed) to form a) an element b) a compound c) a mixture. They can represent atoms being joined or bonded together by having sticks between the seeds/kernels.
6. After 5 minutes, tell the groups to finish and ask them to move around looking at other groups results. Ask trainees:
 - a. Did each group have the same results? e.g. use the same seeds/kernels to show elements, compounds and mixtures

Answer: Probably NO, the groups will have all used different seeds/kernels; some compounds may have been made up of all 4 seeds/kernels; others only 2; some mixtures may have used all 4 seeds/kernels, others only 2 and elements could have been shown by any of the individual seeds/kernels)
7. Explain to trainees; that this exercise shows that there are many different elements, compounds and mixtures around us. There are over 100 elements that have been discovered by humans, the names of these elements are all put in a table called the Periodic Table. Examples of elements that most people have heard of include gold, silver, tin, carbon, oxygen, nitrogen. There are NO compounds or mixtures in the Periodic Table. We shall look in more detail at the Periodic Table in a different topic.
8. Give each group of trainees a set of cards (mix them up). Let them know this is a competition. When you say a word, the group must find the card that matches the word and hold it up. Points will be given for the first correct answer; no shouting out is allowed.

Examples of possible cards (you can draw them how you want):



Atoms of an element

Mixture

Molecule of an element

Compound

Molecule of 2 elements

9. Make sure you keep score! Start the game by calling out the first:
 - a. Atoms of an element
 - b. Mixture
 - c. Molecule of an element
 - d. Compound
 - e. Molecule of 2 elements

10. Refer trainees to the **3. 1 Key Facts** and answer any questions regarding the differences between atoms, molecules, elements, compounds and mixtures.



Guided Practice Activity

1. Before class, arrange materials in the room. Each group will need a small cup of water, a tablespoon of salt, 3 tablespoons of flour, 1 tablespoon of sugar and a small amount (pinch) of yeast. Small containers, spoons or other stirring implements are needed.

2. Ask trainees to stay in groups of 4-5, give each group the materials listed above. Ask trainees: what can be made from these ingredients? **Answer:** bread/dough. Tell trainees to start making the bread dough. Let the dough 'rest'.

3. Give each group a small cup of water and a tablespoon of salt. Ask trainees: what will happen when the salt is added to the water. **Answer:** the salt sinks to the bottom of the container and then it disappears/dissolves in the water.

4. Ask groups 2 questions:
 - a. Is it possible to get the salt back from the water? If yes, how, if no, why not?
 - b. Look at your dough. Is it possible to get the flour, sugar and yeast from the dough you have made? If yes, how? If no, why?
5. Encourage groups to try out their suggestions!
6. Ask groups:
 - a. Do you think the salt and water is an element, mixture or compound?
Answer: Mixture, because it is possible to separate the salt from the water.
 - b. Do you think the bread dough is an element, mixture or compound?
Answer: compound as it is not possible to separate the yeast, water, flour and sugar.
7. Say: Mixtures can be separated; for example, sugar from water (by boiling/evaporation), salt from water (by boiling/evaporation), flour from sugar (sifting) BUT compounds cannot be separated; this is because they have formed bonds that are called **chemical bonds** with each other. These bonds are very difficult to break and usually need other chemicals or a lot of energy in the form of heat to break them down; for example, iron ore is a compound and very high temperatures are needed to get the iron from the rock.



Application Activity

1. Before class have a small bucket of water mixed with mud, sand and stones. Have smaller containers for each group and some old cloth of different types.
2. Tell trainees that it is very important to know about mixtures and compounds as we need this information for many of the everyday jobs that we do and that one of these is mining.
3. Ask trainees to think of everything they have learnt about atoms, molecules, elements, compounds and mixtures and to answer the following questions.

Gold

- a. Where do you find gold?
Answer: often mixed with mud, sand and water, (in some places in Rwanda, gold can be found in a rock as a vein of gold).

- b. Do you think the gold with the mud and sand are an element, mixture or compound? Why?

Answer: Mixture as the mud, sand and gold can all be separated out.

- c. When you have separated the gold from the mud and sand, do you think the gold is an element, compound or mixture? Why?

Answer: the gold is an element as it cannot be broken down into anything simpler, gold is made up of gold atoms and nothing else.

Tin ore

- a. How is tin found? For example as tin, or as dust or as a rock?

Answer: it is found as a rock

- b. What is this tin with rock called?

Answer: this rock is called tin ore

- c. Can the tin in this rock be used straight away or does it need to be processed?

Answer: no, it can't be used straight away, it needs to be processed in some way to get the tin out of the rock

- d. Do you think the tin ore is an element, compound or mixture? Why?

Answer: the tin ore is a compound as it is very difficult to separate the tin from the rock, it takes a long process including smelting (heating the tin ore to a very high temperature) to break the chemical bonds joining the tin with the ore.

4. Ask trainees to get into groups of 4-5. Refer them to Topic 3.1 Task 6. Explain that they have been asked by a local school for help as their water supply is full of leaves, sand and mud. Their task is to work out how to provide the school with clean water. The school has provided each group with a small sample of the water.
5. Tell trainees they must work together to get the cleanest water possible for the school; they need to make sure that they document/write down the process they used. Remind groups that they must first think if the dirty water is a compound, mixture or element.
6. After groups have finished, ask them to compare their sample of water to see which group has achieved the cleanest water. Ask group representatives from a selection of groups to explain their process. Other groups can add new or different information.



Points to Remember

- **Atoms** are the smallest building block of all matter or everything around us and can only be seen with a very strong microscope.
- **Elements** are made up of only ONE type of atoms. All elements are listed on the Periodic Table of Elements. For example, gold, carbon, oxygen and sulphur are all examples of elements.
- A **molecule** is made up of 2 or more atoms joining together. These atoms can be of the same or different types.
- A **compound** is made of 2 or more different types of atom joining together. They are very difficult to break down into individual atoms because of the strong chemical bonds holding them together.



Formative Assessment

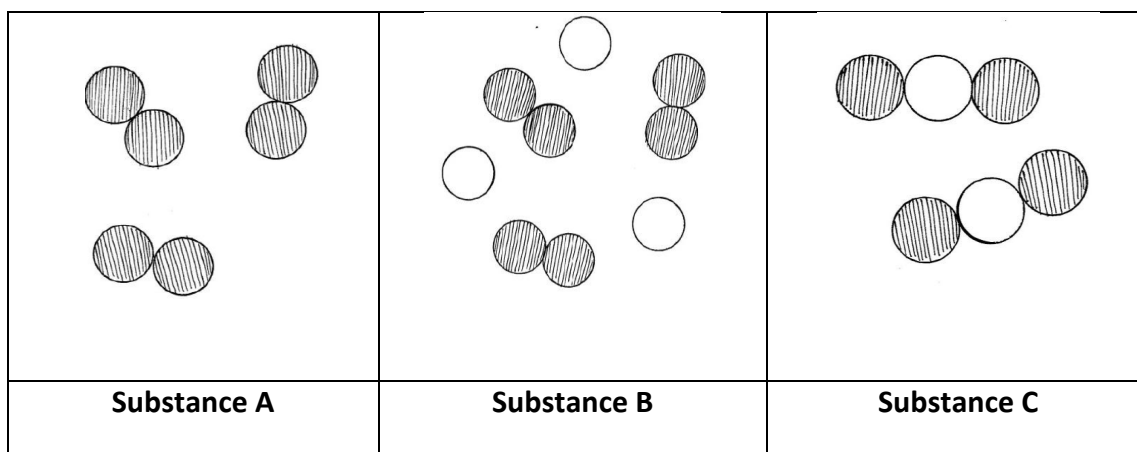
Tell trainees to answer the following questions. Trainees should answer the questions independently in their books without asking other trainees for help.

Select the correct answer:

1. An atom:
 - a. Is the smallest building block known to man
 - b. Can be broken down into smaller parts
 - c. Is the same size as a grain of sand
 - d. Is larger than a grain of salt

Answer: a) is the smallest building block known to man

2. Look at the 3 diagrams below:



- a. Which diagram shows a molecule made up of only one element? (*Answer: Substance A*)
 - b. Which diagram shows a molecule made up of 2 elements? (*Answer: Substance C*)
 - c. Which diagram shows a mixture? (*Answer: Substance B*)
3. A mixture of sugar and water:
- a. Cannot be separated
 - b. Can be separated into sugar and water
 - c. Forms a compound

Answer: b) can be separated into sugar and water

4. Bread is made up of different ingredients. Bread is:
- a. A mixture
 - b. A compound
 - c. An element

Answer: b) compound

5. Compounds are made up of 2 or more elements. Compounds can:
- a. Be easily separated into the different elements
 - b. Not be easily separated into the different elements
 - c. Are the same as mixtures

Answer: b) not be easily separated into the different elements

Further Information for the Trainer

1. <https://www.khanacademy.org/science/biology/chemistry--of-life/elements-and-atoms/a/matter-elements-atoms-article?modal=1>
2. Study.com is a website that offers lessons, videos, and quizzes.
<https://study.com/academy/lesson/understanding-the-relationships-between-elements-molecules-compounds.html>
3. Gagnon, S. (n.d.) What is the simplest way of explaining what atoms, elements, compounds and mixtures are? Retrieved from
https://education.jlab.org/qa/atom_02.html
4. Helmenstine, A. M. (July 03, 2019). Is Water a Compound or an Element? Retrieved from <https://www.thoughtco.com/is-water-a-compound-609410>.
5. The Structure of the Atom. Retrieved from
<https://courses.lumenlearning.com/boundless-chemistry/chapter/the-structure-of-the-atom/>

Learning Outcome 3.2: Explore the linkages between the atomic structure and the positions of elements on the periodic table

	Objectives: By the end of the learning outcome, trainees will be able to: - Explore the simple model of an atom (neutrons, electrons and protons) - Explore the first 20 elements of the periodic table showing elements are arranged in order of atomic mass - Describe the difference between atomic mass number and atomic number - Identify position of elements in periodic table according to atomic structure and arrangement of outer electrons
	Time Required: 14 hours
	Learning Methodology: small group work; pair work; brainstorming, practical
	Materials Needed: - Small stones, seeds, beads of at least 3 different types. Each group will require approximately 20 seeds/beads/stones of each type. - Periodic Table – large poster if possible - Metal spoons and small pieces of charcoal – each group of 4-5 trainees will have one of each
	Preparation: ☐ Ensure you have all the required materials listed above ready and prepared.
	Cross Cutting Issues: ✓ Gender and Inclusiveness: Ensure groups where possible are mixed female and male. Mix different ages of students where possible. Encourage equal representation of male/female/young/older trainees to answer questions, present results and to be engaged in all activities.
	Prerequisites: ▶ Basic understanding of atoms, molecules, compounds, mixtures and elements

Key Competencies:

Knowledge	Skills	Attitudes
1. State names and chemical symbols of the first 20 elements in the Periodic Table	1. Determine key uses of common elements	1. Develop curiosity about naming and use of some common elements
2. Describe the internal structure of an atom	2. Draw and label the internal structure of the atom	2. Pay attention to details
3. Identify how electrons are arranged in shells around the atom's nucleus	3. Draw the electronic structure of any of the first 20 elements in the Periodic table	3. Be precise when recreating models
4. Define atomic mass number and atomic number	4. Classify elements based on atomic mass	4. Realize the importance of the Periodic Table of Elements



Steps:



Getting Started: What do we know and where are we going?

Topic 3.2 Task 1: Activity to investigate how different objects in nature are organized.

1. Give each group of 3-4 trainees a selection of small sticks, stones, seeds, beads, these should be all mixed together.
2. Tell each group to organize the objects into groups. Tell trainees that you will give them no other information.
3. Ask groups to then arrange their objects in a different way.
4. Ask trainees, how did you organize your objects? **Possible Answers:** by type of object, by shape, by color, by size, etc.
5. Explain: there are different ways in which we can organize these objects.
6. Ask trainees to think of their own homes and what they may organize/group. **Possible answers:** kitchen utensils and crockery, clothes, books, furniture.

7. Explain: in Chemistry, scientists decided to organize all the different elements that we find. This makes it easier to study, scientists have grouped elements which have similar properties; for example, metals and non-metals are grouped separately. In this topic, we will look at how the elements are organized in the **PERIODIC TABLE** and find out why scientists ordered them in this way.

Topic 3.2 Task 2: What elements do we know?

8. Ask trainees to turn to **Topic 3.2 Task 2:** in pairs to write in their notebooks as many different elements that they can think of and what their use may be.
9. Ask pairs to put their hands up if they could:
- Name more than 5 elements including their use
 - Name more than 10 elements including their use
 - Name more than 20 elements including their use
10. Ask different pairs to name 2-3 elements with their uses. Repeat 3-4 times.
11. Ask trainees to look in their manual at the PERIODIC TABLE. Explain: the table shows all elements known to man and if your substance is NOT found on the periodic table this means that it is NOT an element; for example, wood is NOT an element, it is made up of carbon, nitrogen and oxygen. Ask pairs of trainees to find 3-4 of the elements they named in the previous activity.
12. Ask trainees:
- Is each element made up of one type of atom or more than one type of atom?
Answer: Each element is made up of one type of atom only.
 - Does anyone know what is found inside each atom?
Answer: Accept all answers stating that we will discover if our initial thoughts were correct as we go through this topic.
13. Explain that this topic will look at: the simple model of the atom, how this relates to where elements are placed on the Periodic Table and some of the properties or characteristics of some elements.



Problem Solving Activity

Topic 3.2 Task 3: Identifying patterns

1. Ask trainees in pairs to look at the Periodic Table and to identify any patterns; for example; do they notice anything about any of the numbers by the elements, or the groupings of elements? Let 2-3 pairs share their findings.
2. Explain: The first element has a number 1 and the elements are ordered with numbers going sequentially e.g. 1, 2, 3, 4, 5..... There are Roman numeral numbers going across the top of the Periodic Table from I to VIII. The elements seem to be divided into metals and non-metals. Each element has a symbol, for example hydrogen has the symbol H and aluminium has the symbol Al

Topic 3.2 Task 4: Metals and non-metals

3. Have trainees turn to **Topic 3.2 Task 4**. Divide trainees into groups of 4 – 5 people and give each group 1 piece of charcoal and a spoon. Ask groups to discuss and fill in the table in their books about the properties or characteristics of the charcoal and spoon

Property	Spoon	Piece of Charcoal
What does it look like?		
What is it like at room temperature?		
Does it feel heavy or light for its size?		
How strong is it?		
Can it break easily?		
Does it get warm easily?		
Does it let electricity pass through it?		
What sound does it make when you hit it?		

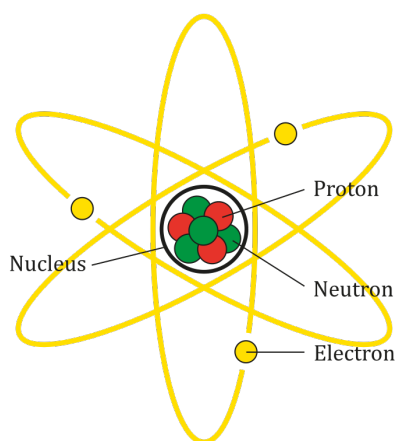
4. Ask different groups to read out one property for the charcoal and spoon
5. Explain key characteristics/properties of metals and non-metals.

6. Ask: Is the spoon a metal or non-metal? (Answer: metal) Is the piece of charcoal a metal or non-metal? (Answer: non-metal).
7. Ask: What do you think are the characteristics or properties of metal and non-metals based on the investigation that you have just done?

Answer: All metals have the same characteristics or properties as described above; they are shiny, conduct electricity, are hard to break, make a ringing sound when hit, get warm easily, are strong, usually solid at room temperature. Non-metals are usually dull in colour, do not conduct electricity, break easily, makes a dull sound when hit. They can be solid (charcoal), liquid (bromine) or gas (hydrogen, oxygen...)

Topic 3.2 Task 5: Structure/model of an atom

8. Say: When we looked at the Periodic Table, we noticed that each element had 2 different numbers, we are now going to investigate what those numbers mean by looking at the structure of an atom.
9. Ask trainees in pairs to look at the picture of the atom in their books in **Topic 3.2 Task 5**. Ask them to describe what they see. Ask 2-3 pairs to present what they see.



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10. Explain: Each atom contains a centre part which is where most of the atom's mass is; this is called the **NUCLEUS**. The nucleus contains 2 types of very small particles called **NEUTRONS** and **PROTONS**. Surrounding the nucleus in rings are **ELECTRONS**. These rings are called **SHELLS**; think of them as the different layers of an onion. **NEUTRONS** are neutral meaning that they have no charge and are **NOT** attracted or repelled by anything.

¹⁵ User:AG Caesar. (2018, March 4). *Atom diagram* [SVG image]. Wikimedia Commons. https://commons.wikimedia.org/wiki/File:Atom_Diagram.svg
License: <https://creativecommons.org/licenses/by-sa/4.0/legalcode>

PROTONS have a positive charge and **ELECTRONS** have a negative charge.

11. Tell trainees: fill in the table to show the different properties of electrons, protons and neutrons.

Properties	Electrons	Protons	Neutrons
Location	In shells around the nucleus	Nucleus	Nucleus
Charge	Negative (-ve)	Positive (+ve)	Neutral (no charge)
Size	Smallest	Large	Large

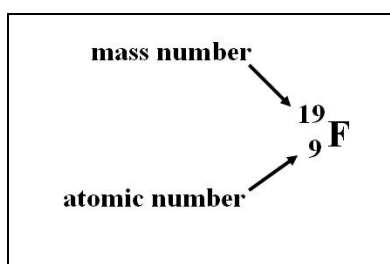
12. Go through the correct answers with trainees.

Atomic number and Atomic Mass Number

13. Say: Many of you noticed that on the periodic table for each element there are 2 numbers. The top number is called the **ATOMIC NUMBER**. Sometimes this is called the **PROTON** number because it tells us how many protons are in the atom of this element. The bottom number is called the **ATOMIC MASS NUMBER** and is the number of protons and neutrons in the atom of this element. The number of protons equals the numbers of electrons.

14. Tell trainees to look at the example in their books in **Topic 3.2 Task 5**.

Note: This is standard atomic notation. Also have them look for F in the Periodic Table to see how the mass number and atomic number are presented there.



15. Ask trainees to answer the following questions.
- What element has the symbol 'F'? **Answer:** Fluorine
 - Which number shows you the numbers of protons and neutrons in an element? (**Answer:** Atomic mass number or Mass number)
 - How many protons are in this element? **Answer:** 9 protons
 - How many neutrons are in this element? **Answer:** 10 neutrons (no. of neutrons = mass number – atomic number, $19 - 9 = 10$ neutrons)
 - How many electrons are in this element? **Answer:** 9 electrons (no. of electrons = no. of protons)

Electronic structure

16. Ask trainees:

- a. Where are electrons found in an atom? **Answer:** in shells/circle moving around the nucleus.
- b. How do you calculate the number of electrons in an atom? **Answer:** the number of electrons = the number of protons.

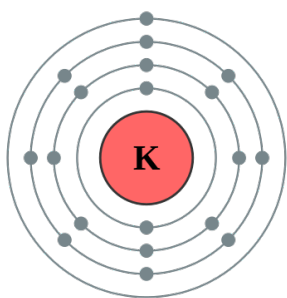
17. Say: In each shell of electrons surrounding the nucleus of protons and neutrons, there can only be a certain number of electrons in each shell.

- a. In the first shell (closest to the nucleus), there can be a maximum of 2 electrons
- b. In the second shell (surrounding the first shell), there can be a maximum of 8 electrons
- c. In the third shell (surrounding the second shell), there can be a maximum of 8 electrons
- d. In the fourth shell (surrounding the third shell), there can be a maximum of 18 electrons.
- e. The shells fill up from the inside (nearest to the nucleus) to the outside

18. Ask learners to turn to **Topic 3.2 Task 6** and to look at the following example for the Potassium element which has an atomic number of 19 meaning 19 protons and 19 electrons. We can write the electronic configuration for Potassium as 2.8.8.1 or draw a diagram. This shows that there are 2 electrons in the first shell, 8 in the second, 8 in the third and 1 in the fourth (total 19 electrons).

19: Potassium

2,8,8,1



16

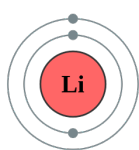
19. Say: Look at the Lithium atom and answer the following:

¹⁶ Robson, G. (n.d.). *Electron shell 019 Potassium*. Wikimedia

Commons. https://commons.wikimedia.org/wiki/File:Electron_shell_019_Potassium.svg

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- a. What is the atomic number of Lithium? **Answer: 3**
- b. How many protons are there in a Lithium atom? **Answer: 3 protons**
- c. How many electrons are there in a Lithium atom? **Answer: 3 electrons**
- d. How many electrons in the Lithium atom, will there be:
 - i. In the first shell? **Answer: 2 electrons**
 - ii. In the second shell? **Answer: 1 electron**
 - iii. In the third shell? **Answer: 0 electrons**
- e. Write the electronic structure of a Lithium atom. **Answer: 2.1**



17

20. Explain: Electrons start to fill up the shells from the inside out. Once when shell is full, the next shell starts to be filled. The number of the electrons in the outer shell will tell you what GROUP an element is in. There are 8 groups in total in the Periodic Table and these groups go from left to right.
21. Ask trainees to continue with the questions:
 - a. Look on the Periodic Table, the numbers of the Groups are often written as Roman numerals e.g. I = Group 1, II = Group 2, V = Group 5 etc.
 - b. Look at the Lithium atom that you just wrote and drew the electronic structure for. How many electrons are in the outer shell? **Answer: 1 electron**
 - c. If Lithium has one electron in its outer shell, what group is it in? **Answer: Group I or 1.**
22. Refer trainees to **3.2 Key Facts** for a summary of information regarding elements, the Periodic Chart and the parts of the atom.

¹⁷ Robson, G. (n.d.). *Electron shell 003 Lithium*. Wikimedia Commons. https://commons.wikimedia.org/wiki/File:Electron_shell_003_Lithium.svg
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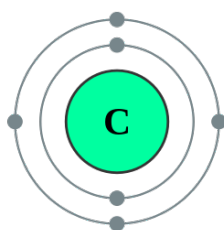


Guided Practice Activity

1. Refer trainees to **Topic 3.2 Task 7** and divide them into groups of 2-3 trainees. Give each group the following: small beads/seeds of different colors/types. Tell groups that they must work out what beads/seeds/beans represent neutrons, electrons and protons.
2. Ask groups to illustrate with beads, beans or seeds the atomic structure of the following elements:
 - a. Carbon
 - b. Magnesium

6: Carbon

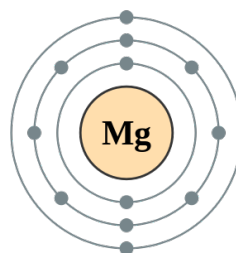
2,4



18

12: Magnesium

2,8,2



19

Hint: First, trainees must work out the number of neutrons, protons and electrons.

Check atomic structures with groups of trainees.

3. Tell groups to choose any 2 elements from the first 20 elements on the periodic table and to show the atomic structure using the beads/beans or seeds. Tell groups NOT to let other groups know what element they have chosen!

¹⁸ Robson, G. (n.d.). *Electron shell 008 Oxygen - no label*. Wikimedia Commons. https://commons.wikimedia.org/wiki/File:Electron_shell_008_Oxygen_-_no_label.svg
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¹⁹ Robson, G. Q. (n.d.). *Electron shell 012 Magnesium*. Wikimedia Commons. https://commons.wikimedia.org/wiki/File:Electron_shell_012_Magnesium.svg
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4. Ask each group to look at ONE other group's work and to work out which element they have shown.
5. Tell trainees to look in their books and to fill in the missing information about atomic numbers or names/symbols of elements. The first one has been done for them.

Name of element	Symbol of element	Atomic number	No. of protons	No. of electrons	No. of neutrons	Atomic Mass Number
Carbon	C	6	6	6	6	12
Sodium	Na	11	11	11	12	23
Magnesium	Mg	12	12	12	12	24
Phosphorus	P	15	15	15	16	31
Argon	Ar	18	18	18	22	40
Aluminium	Al	13	13	13	14	27

6. Go through answers with trainees.

Topic 3.2 Task 8: Electronic structure

7. Refer trainees to **Topic 3.2 Task 8**. Review electronic structure by asking:

- a. Where do you find electrons in an atom?

Answer: in shells or circles around the nucleus

- b. In an atom, are there the same number of electrons and neutrons OR electrons as protons?

Answer: the number of electrons is the same as the number of protons

- c. What is the maximum number of electrons in the first shell/circle?

Answer: 2 electrons

- d. Is this shell closest to the nucleus or furthest from the nucleus?

Answer: closest to the nucleus

- e. What is the maximum number of electrons in the 2nd shell?

Answer: 8 electrons

- f. What is the maximum number of electrons in the 3rd shell?

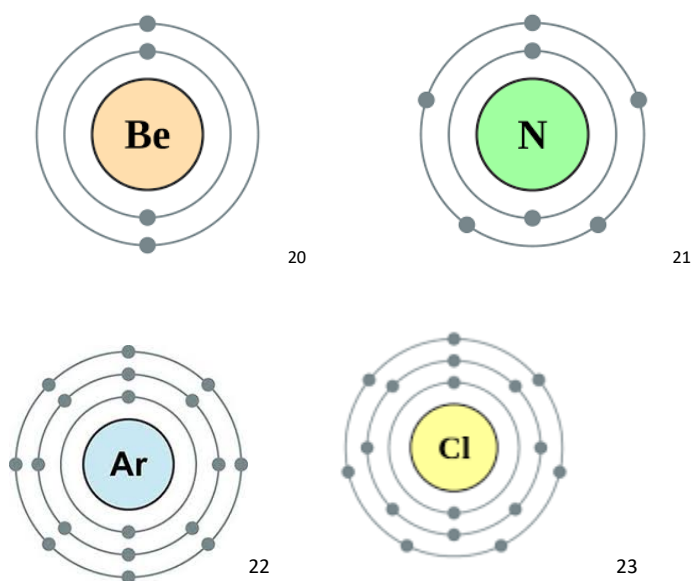
Answer: 8 electrons

- g. What does the number of electrons present in the outermost shell tell you about the element?

Answer: it tells you what group the element is in, for example Fluorine has 7 electrons in its outermost shell meaning it is in Group VII (7)

8. Give groups of 2-3 trainees, beads, seeds or beans. Tell trainees the beads/seeds/beans are electrons.
9. Tell groups to use the beads/seeds/beans to show the electronic structure for the following elements:
- Beryllium
 - Nitrogen
 - Argon
 - Chlorine

Answer:



²⁰ Robson, G. (n.d.). *Electron shell 004 Beryllium*. Wikimedia Commons. https://commons.wikimedia.org/wiki/File:Electron_shell_004_Beryllium.svg
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²¹ Robson, G. (n.d.). *Electron shell 007 Nitrogen*. Wikimedia Commons. https://commons.wikimedia.org/wiki/File:Electron_shell_007_Nitrogen.svg
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²² Robson, G. (n.d.). *Electron shell 018 argon*. Wikimedia Commons. https://commons.wikimedia.org/wiki/File:Electron_shell_018_argon.png
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²³ Robson, G. (n.d.). *Electron shell 017 Chlorine (el)*. Wikimedia Commons. [https://commons.wikimedia.org/wiki/File:Electron_shell_017_Chlorine_\(el\).svg](https://commons.wikimedia.org/wiki/File:Electron_shell_017_Chlorine_(el).svg)
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10. Groups should draw and write the electronic structure for each of the atoms and identify what group each of the elements belong to.

11. Go through the answers with the trainees:

Beryllium = 2.2 (Group II (2))

Nitrogen = 2. 5 (Group V (5))

Argon = 2.8.8 (Group VIII (8))

Chlorine = 2.8.7 (Group VII (7))



Application Activity

- 1.** Refer trainees to **Topic 3.2 Task 9** and read the following to trainees:
 - a.** A small group of secondary students have heard that you are learning about the Periodic Table and atomic structure. They want your help as their teacher has been sick and they have only been learning from the textbooks. The secondary students want to know the following:
 - i.** The differences between a metal and non-metal
 - ii.** The structure of an atom
 - iii.** The difference between the atomic number and atomic mass number
 - iv.** The numbers of protons, electrons and neutrons in one atom of aluminium.
 - v.** The electronic structure of aluminium (Drawing/written configuration and what group the element is in)
 - vi.** The uses of aluminium and why carbon cannot be used in the same way.
- 2.** Explain that trainees can work in groups of 3 and that some groups will be asked to 'teach'/show their explanations to other groups who will pretend to be secondary school students.
- 3.** Ask 3 groups to present or teach on different parts e.g. Group 1 can present on i and ii Group 2 on iii and iv and Group 3 on v and vi.
- 4.** Revise main points with trainees.



Points to Remember

- All elements are found in the Periodic Table and are represented with a symbol. E.g. C for carbon; Al for aluminium.
- Elements are ordered in the Periodic Table according to their atomic number.
- The atomic number tells you the number of protons in the atom.
- The atomic mass number is the number of protons AND neutrons in an element.
- The number of neutrons can be worked out by atomic mass number – atomic number.
- The number of protons is the same as the number of electrons in an atom.



Formative Assessment

1. Select ALL the answers that are correct:

Metals:

- a. Conduct electricity
- b. Break easily
- c. Look dull
- d. Are usually solid at room temperature

Answer: a) conduct electricity d) are usually solid at room temperature

2. Use the following words to complete the sentences:

Positive	Negative	Nucleus	Electrons	Protons	Neutrons
----------	----------	---------	-----------	---------	----------

Each atom contains a centre part which is where most of the atom's mass is; this is called the **NUCLEUS**. The nucleus contains 2 types of very small particles called NEUTRONS and **PROTONS**. Surrounding the nucleus in rings are **ELECTRONS**. These rings are called **SHELLS**; think of them as the different layers of an onion. **NEUTRONS** are neutral meaning that they have no charge and are **NOT** attracted or repelled by anything. **PROTONS** have a **POSITIVE** charge and **ELECTRONS** have a **NEGATIVE** charge.

3. Select the correct answer:

The ATOMIC NUMBER is:

- a. The same as the ATOMIC MASS NUMBER
- b. The same as the PROTON NUMBER
- c. The same as the PROTON NUMBER and ATOMIC MASS NUMBER

Answer: b) the same as the PROTON NUMBER

4. The element carbon has 6 protons and 6 neutrons, what is the atomic mass number for carbon?

Answer: the atomic mass number for carbon is 12

5. The element sodium has an atomic number of 11. Write the electronic configuration for sodium.

Answer: the electronic configuration for sodium is 2.8.1

6. Select the correct answer:

Chlorine has an electronic configuration of 2.8.7. Chlorine is in:

- a. Group 17 of the Periodic Table
- b. Group 7 of the Periodic Table
- c. Group 2 of the Periodic Table
- d. Group 8 of the Periodic Table

Answer: b) Group 7 (the numbers of electrons in the outer shell (7 for Chlorine) show the group number.

Further Information for the Trainer

- 1. Khan Academy is a good resource for many subjects, including chemistry. They have lessons, videos, tests, etc. that can be integrated into your own lessons. Isotopes are not discussed in this Learning Unit but it is included here along with atomic number and atomic mass: <https://www.khanacademy.org/science/biology/chemistry--of-life/elements-and-atoms/a/atomic-number-atomic-mass-and-isotopes-article>
- 2. <https://www.bbc.co.uk/bitesize/guides/z84wjxs/revision/1>

Learning Outcome 3.3: Apply knowledge of atomic structure to the formation of chemical bonds

	Objectives: By the end of the learning outcome, trainees will be able to: - Explain and illustrate what co-valent bonding is - Explain and illustrate what ionic bonding is - Predict if an element will bond ionically or co-valently
	Time Required: 8.5 hours
	Learning Methodology: small group work; pair work; brainstorming, practical
	Materials Needed: - Small stones, seeds, beads of at least 3 different types. Each group will require approximately 20 seeds/beads/stones of each type. - Periodic Table – large poster if possible
	Preparation: ☐ Ensure you have all the required materials listed above ready and prepared.
	Cross Cutting Issues: ✓ Gender and Inclusiveness: Ensure groups where possible are mixed female and male. Mix different ages of students where possible. Encourage equal representation of male/female/young/older trainees to answer questions, present results and to be engaged in all activities.
	Prerequisites: ▶ Basic understanding of the parts of an atom

Key Competencies:

Knowledge	Skills	Attitudes
1. Define what an ion is	1. Calculate the charge of an ion for metals and non-metals in Groups I, II, III and VI and VII	1. Pay attention to detail
2. Recognise that metals form positive ions by losing electrons and non-metals form negative ions by gaining electrons	2. Draw simple ionic diagrams for some elements	2. Show an enquiring mind for determining if elements will form covalent or ionic bonds
3. Recognise that ionic bonds form when metals and non-metals react together to form a compound	3. Illustrate how metals and non-metals can form ionic bonds	3. Be precise when recreating models



Steps:



Getting Started: What do we know and where are we going?

1. Tell trainees that they are going to have a competition and they can work in pairs. Explain that a question will be read out (questions can also be found in the Trainee's Manual in **Topic 3.3 Task 1**) and that they must write their answer on paper. Other pairs should not be able to see other pair's work.
 - a. Give an example of 2 molecules
Answer: any 2 molecules
 - b. How do molecules form?
Answer: when 2 atoms from 1 or more element join by chemical bonds
 - c. When do compounds form?
Answer: when 2 non-metals react together, or a metal and a non-metal react together
 - d. Table salt is made up of two elements, the metal sodium and the non-metal chlorine. The compound formed is sodium chloride and is what we use to flavor our

food. Is it possible to break sodium chloride into the metal sodium and the non-metal chlorine? Explain.

Answer: No, the bonds that join the elements together to form a compound or molecule are very strong meaning that a lot of energy is needed to break these.

- e. Write the chemical symbol for chlorine.

Answer: Cl

- f. Write the electronic structure for chlorine which has an atomic number of 17 and atomic mass number of 35.

Answer: 2.8.7

- g. What is the maximum number of electrons that can be found in the third electron shell?

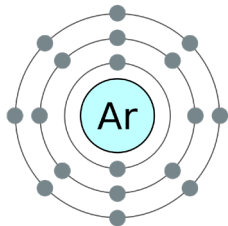
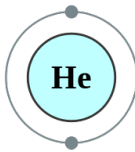
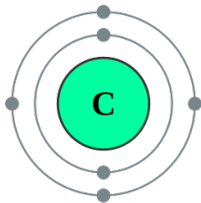
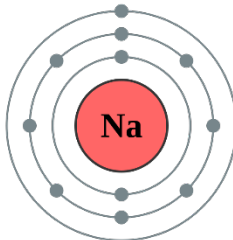
Answer: a maximum of 8 electrons

2. Go through answers with trainees explaining that there is one mark for each correct answer. Ask pairs to score their answers. Give congratulations to the winning pair(s).
3. Explain that this topic will look at how and why compounds and molecules are formed by looking at the electronic structure of elements.



Problem Solving Activity

1. Explain that if the outer electron shell is full, this will make the element stable. If the outer electron shell is not full, this makes the atom of the element unstable and the element will want to react either with itself to form a molecule e.g. hydrogen or nitrogen or with another element e.g. sodium and chlorine for form sodium chloride (Table salt).
2. Refer trainees to **Topic 3.3 Task 2** and show different diagrams of the electronic structure of some elements. Ask trainees if these elements are stable or unstable.
3. Explain: Only the elements in Group VIII (8) in the Periodic Table are stable as they have full outer electron shells. All the other groups contain elements that are not stable and want to react to become stable.

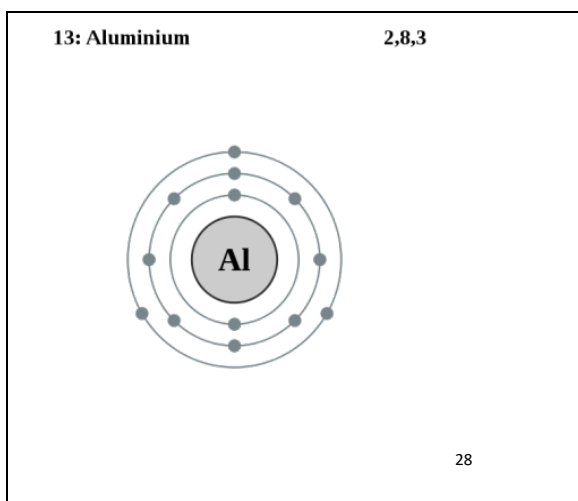
18: Argon 2,8,8  24	2: Helium 2  25
6: Carbon 2,4  26	11: Sodium 2,8,1  27

²⁴ Robson, G. (n.d.). *Electron shell 018 argon*. Wikimedia Commons. https://commons.wikimedia.org/wiki/File:Electron_shell_018_argon.png
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²⁵ Robson, G. (n.d.). *Electron shell 002 Helium*. Wikimedia Commons. https://commons.wikimedia.org/wiki/File:Electron_shell_002_Helium.svg
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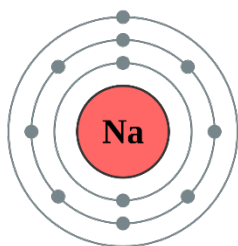
²⁶ Robson, G. (n.d.). *Electron shell 006 Carbon*. Wikimedia Commons. https://commons.wikimedia.org/wiki/File:Electron_shell_006_Carbon.svg
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²⁷ Robson, G. (n.d.). *Electron shell 011 Sodium*. Wikimedia Commons. https://commons.wikimedia.org/wiki/File:Electron_shell_011_Sodium.svg
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4. Say: Look at the diagram of the atom of sodium (Chemical symbol Na) found in **Topic 3.3 Task 3**.

11: Sodium 2,8,1



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- a. How do you think this atom of sodium can become stable?
Possible answer: It could gain 7 electrons to make the 3rd shell full or it could lose 1 electron from the 3rd shell so that the 2nd shell is full.
- b. Is it easier for a sodium atom to gain seven electrons or lose one electron?
Answer: to lose one electron.
- c. If sodium loses one electron, how many electrons and protons does it now have?

²⁸ Robson, G. (n.d.). *Electron shell 013 Aluminium*. Wikimedia Commons. https://commons.wikimedia.org/wiki/File:Electron_shell_013_Aluminium.svg
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²⁹ Robson, G. (n.d.). *Electron shell 011 Sodium*. Wikimedia Commons. https://commons.wikimedia.org/wiki/File:Electron_shell_011_Sodium.svg
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Answer: 11 protons and 10 electrons

5. Give groups of 2-3, beads/seeds/beans to depict electrons and protons. Ask trainees to use the beans/beads or seeds to show the number of protons and the electronic structure for lithium and fluorine.

6. Ask trainees to:

- a. Work out if these elements will lose or gain electrons.

Answer: Lithium will lose one electron and fluorine will gain one electron to become stable

- b. Calculate and write down the number of protons and electrons for lithium and fluorine.

Answer: Lithium will have 3 protons and 2 electrons, fluorine will have 9 protons and 10 electrons

7. Ask trainees:

- a. What charge do protons carry?

Answer: positive charge

- b. What charge do electrons carry?

Answer: negative charge

- c. For lithium, when it has lost an electron, are there more protons or electrons?

Answer: more protons

- d. Does this mean that there is more positive or negative charge?

Answer: more positive charge

- e. How many more positives or protons are there than negatives or electrons?

Answer: 1 more positive charge

8. Explain: When an atom loses or gains an electron, it is no longer called an atom but an ION. Because lithium has an extra proton, this means it has a positive charge of 1 and this is written as Li^{+1} .

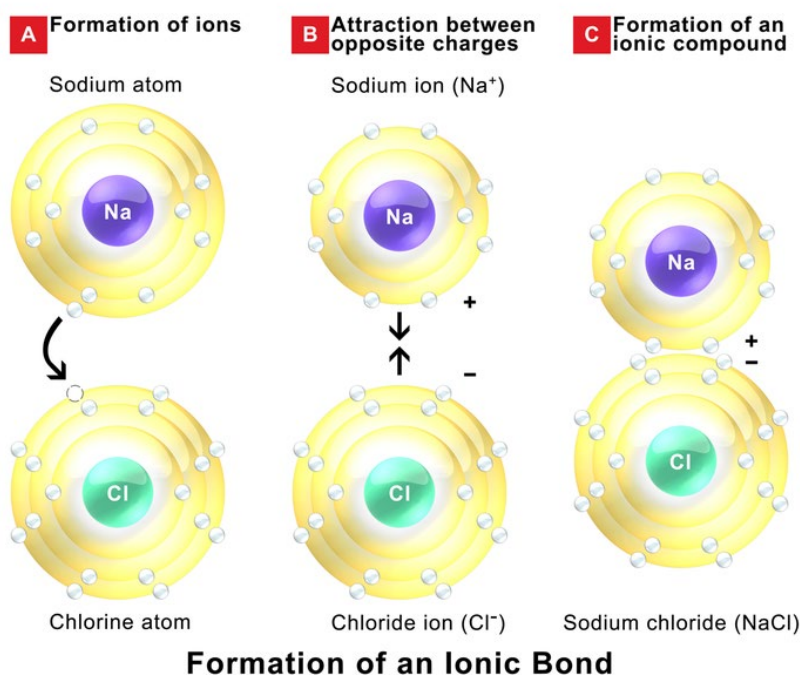
9. Repeat for fluorine.

Answer: Fluorine has one extra electron meaning it has more electrons than protons, this means it has an extra negative charge and the ion of Fluorine would be written as F^{-1} .

Topic 3.3 Task 4: Forming Ionic compounds between a metal and non-metal

10. Explain: Metals and non-metals will react together to form a compound; for example, the metal sodium reacts with the non-metal chlorine to form the ionic compound Sodium Chloride.

11. Show the diagram found in **Topic 3.3 Task 4** of how sodium and chlorine gain or lose electrons to form sodium chloride.



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Topic 3.3 Task 5: Sharing electrons – covalent bonds

12. Refer trainees to **Topic 3.3 Task 5**. Have them read and then explain that a different type of bond will form between non-metals and this is when atoms **SHARE** one or more electrons rather than lose or gain electrons. The type of bond formed when electrons are shared is called a **COVALENT BOND**. An atom that shares one or more of its electrons does so to get a full outer electron shell.

13. Tell trainees to use the beads/seeds/beans to first show the electronic structure of hydrogen and chlorine.

14. Ask:

³⁰ Blaus, B. (2015, November 12). *Ionic bonds*. Wikimedia Commons. https://commons.wikimedia.org/wiki/File:Ionic_Bonds.png
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a. What does the hydrogen want to do to become stable?

Answer: have 2 electrons in its outer shell

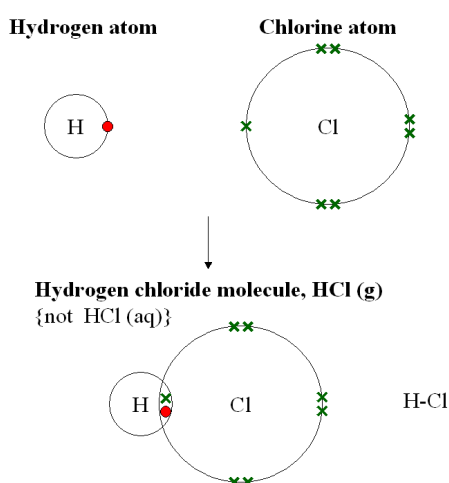
b. What does the chlorine atom want to do to become stable?

Answer: have 8 electrons in its outer shell

c. How can this happen? Remember that non-metals form covalent bonds which means they share electrons rather than losing or gaining electrons like ionic bonds.

Answer: one hydrogen electron and one chlorine electron will be shared; this means that hydrogen will now have 2 electrons making its outer shell full and chlorine will have 8 electrons making its outer shell full.

15. In the diagram below, hydrogen has 1 electron in its outer shell and chlorine has 7. For these atoms to become stable, they react together and form one covalent bond by sharing 1 electron each. The hydrogen now contains 2 electrons in its outer shell and chlorine contains 8 electrons by sharing electrons.



16. Refer trainees to **3.3 Key Facts** for a summary of the information presented above on metals, non-metals and ionic and covalent bonding.



Guided Practice Activity

Determining the charge on an ion

1. Tell trainees, remember that atoms can lose or gain electrons to form ions and you can work this out by looking at the electronic structure of an element. Have them turn to **Topic 3.3 Task 6**.
2. Tell trainees: Calculate the charge for the following elements when they form ions, you can do this any way you like, either with diagrams or using beads/seeds/beans:

- a. Magnesium **Answer** Mg^{+2}
- b. Aluminium **Answer:** Al^{+3}
- c. Oxygen **Answer:** O^{-2}
- d. Helium **Answer:** Does not form an ion as its outermost electron shell is full

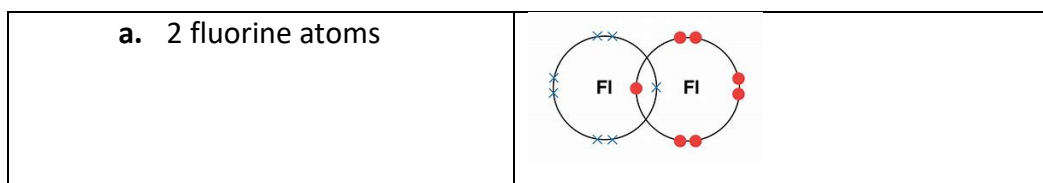
Forming ionic compounds

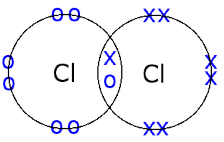
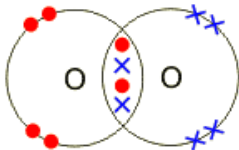
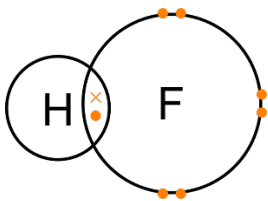
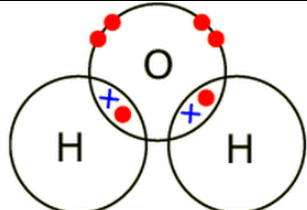
3. Remind trainees that metals and non-metals can react together to form ionic compounds. For example, sodium will transfer the one electron in its outer shell to chlorine. This forms sodium chloride. Remind trainees to look in their books at how sodium and chlorine react together by losing or gaining electrons (in **Topic 3.3 Task 4**).
4. Tell trainees to turn to **Topic 3.3 Task 7** and work in pairs and to use the beads/beans/seeds to show how the following elements react to form compounds:
 - a. Lithium and fluorine to form Lithium Fluoride
 - b. Potassium and Chlorine to form Potassium Chloride
 - c. Magnesium and oxygen to form Magnesium Oxide
 - d. Magnesium and chlorine to form magnesium chloride (hint you can use more than one atom of chlorine)

5. Ask trainees to draw diagrams of how the elements lose or gain electrons to form new compounds. They should follow the example shown in their books for sodium chloride.

Sharing electrons – covalent bonds

6. Ask trainees: Do non-metals react by sharing electrons or losing/gaining electrons?
Answer: by sharing electrons
7. Remind trainees that more than one electron can be shared from any one atom.
8. Ask trainees to turn to **Topic 3.3 Task 8** and work in pairs to show how the following non-metals share electrons to form strong covalent bonds.



b. 2 chlorine atoms	
c. 2 oxygen atoms	
d. 1 hydrogen and 1 fluorine atom to form hydrogen fluoride	
e. 2 hydrogen and 1 oxygen atoms to form hydrogen oxide (known as water)	

9. Go through answers with trainees, using the drawings in the table above to guide you.



Application Activity

1. Read the scenario in **Topic 3.3 Task 9** to the trainees:

The secondary school science teacher is still sick but she has given the students some work to do. She has provided a box with broken up electronic structure models so that the students can learn about ionic and covalent bonding. You must show with the models (beans/ beads and seeds) how a non-metal and metal bond together and how 2 non-metals bond together. You can decide to use any metals or non-metals found in the first 20 elements of the periodic table. Under each model, you must write some brief notes about the formation of your ionic and covalent bonds. You will need to present your work to other members of the class when finished.

2. Ask two groups to present their work (one group can present on ionic bonds and one group can present on covalent bonds). Tell other groups they may ask questions or challenge the groups if they think something is unclear.



Points to Remember

- Metals and non-metals react together to form compounds through ionic bonding. The metals lose electrons and the non-metals gain electrons.
- If an atom loses or gains an electron, it is then called an ION. When it loses an electron, it will have a positive charge. If it gains an electron, it will have a negative charge.
- When non-metals join together, they do this by sharing electrons. For example, to form a molecule of oxygen, O_2 , 2 oxygen atoms each need to share 2 electrons. This is called **COVALENT** bonding.



Formative Assessment

1. Select the correct answer:

In the second electron shell, there can be a maximum of:

- a. 2 electrons
- b. 8 electrons
- c. 10 electrons

Answer: b) 8 electrons

2. Select TRUE or FALSE for the following statement:

If the outer electron shell is not full, the element is stable

Answer: FALSE

3. Select the correct answer:

Ions are formed when:

- a. Electrons are lost only
- b. Electrons are gained only
- c. Electrons are lost or gained
- d. Electrons are shared

Answer: c) electrons are lost or gained

4. Is the following statement TRUE or FALSE:

Covalent bonds are formed when one or more electrons are shared between atoms.

Answer: TRUE

5. Magnesium forms Magnesium ions with a charge of 2+ or Mg^{2+} . The atomic number of a Magnesium atom is 12. Calculate how many electrons a Mg^{2+} ion has.

Answer: 10 electrons

6. Write down the electronic configurations for Lithium and Chlorine (Lithium has an atomic number of 3 and Chlorine has an atomic number of 17).

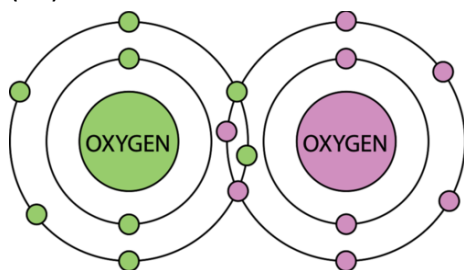
Answer: lithium = 2.1, Chlorine = 2.8.7

7. Draw an electron configuration for how Lithium and Chlorine combine to form Lithium Chloride.

8. Write down the electronic configuration for oxygen (atomic number for oxygen is 8)

Answer: 2.6

9. Show how 2 oxygen atoms combine by sharing electrons to form an oxygen molecule (O_2)



Summative Assessment

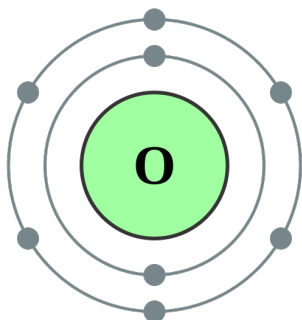
(Questions for Trainees):

Scenario/ integrated situation

Vanessa, a primary five pupil was walking home from school and was very thirsty. She and her friend Jane had no water and decided to drink from a nearby, disused well. The water did not taste good, it was salty, but Vanessa drank a whole cupful whilst Jane spat hers out and said she would wait until she got home before she had a drink. Vanessa got home and fell sick with a headache and stomach pains. She told her mother she had drunk water from the disused well. Vanessa's mother encouraged her to drink fresh water and after 2 days she was feeling better and could go back to school. She told the teacher what had happened, and the teacher decided that the class should spend the whole week studying water! Here are some of the tasks that the teacher set, help Vanessa and her friends solve the problems.

1. Water is made up of hydrogen and oxygen atoms that have bonded together. Is water an element, compound or mixture? (1 mark)

2. The water that Vanessa had drunk contained salt. Describe how Vanessa and her friends could separate the salt from the water. (3 marks)
3. Look at the diagram below of an oxygen atom, label the nucleus and electrons. (2 marks)



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4. Explain what is found in the nucleus of each atom. (1 mark)
5. In the Periodic Table the element oxygen is shown by the symbol O. This is accompanied by 2 numbers, these are written like $^{16}_8\text{O}$. Describe what these 2 numbers are (don't forget to state the names of these numbers!). (4 marks)
6. Draw and write the electronic configuration for oxygen ($^{16}_8\text{O}$) and hydrogen (^2_1H) (4 marks)
7. The chemical formula for water is H_2O meaning that for every ONE oxygen atom, there are TWO hydrogen atoms.
Show how oxygen and hydrogen bond together by sharing electrons. (2 marks)
8. Name the type of bond that forms between atoms when electrons are shared. (1 mark)
9. The salt in the dirty water that Vanessa drank contains the elements sodium and chlorine.
Draw and write the electronic configuration for sodium ($^{23}_{11}\text{Na}$) and Chlorine ($^{35}_{17}\text{Cl}$) (4 marks)
10. The elements sodium and chlorine combine to form a salt called sodium chloride. Is Sodium chloride an element, mixture or compound? (1 mark)

³¹ Robson, G. (n.d.). *Electron shell 008 Oxygen - no label*. Wikimedia Commons. https://commons.wikimedia.org/wiki/File:Electron_shell_008_Oxygen_-_no_label.svg
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11. The sodium and chlorine form sodium chloride by losing and sharing electrons, the chemical formula is NaCl meaning there is ONE sodium atom to every ONE chlorine atom. Use a diagram to show how the sodium and chlorine bond together. (2 marks)
12. Name the type of bond that forms between atoms when electrons are lost or gained. (1 mark)

Answers for Trainer:

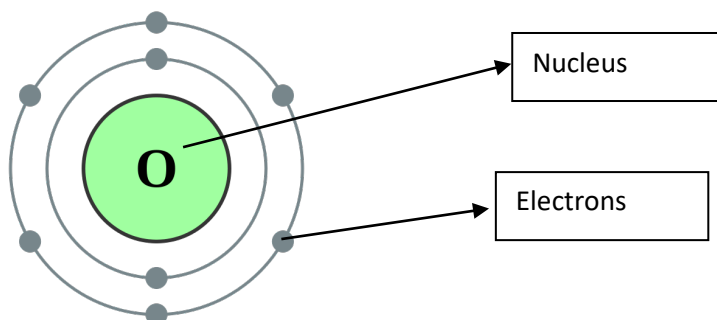
1. Water is made up of hydrogen and oxygen atoms that have bonded together. Is water an element, compound or mixture? (1 mark)

Answer: compound

2. The water that Vanessa had drunk contained salt. Describe how Vanessa and her friends could separate the salt from the water. (3 marks)

Answer: Salt can be removed from water by boiling or evaporating the water. The salt will be left behind as a solid.

3. Look at the diagram below of an oxygen atom, label the nucleus and electrons. (2 marks)



4. Explain what is found in the nucleus of each atom. (1 mark)

Answer: neutrons and protons

5. In the Periodic Table the element oxygen is shown by the symbol O. This is accompanied by 2 numbers, these are written like $^{16}_8\text{O}$. Describe what these 2 numbers are (don't forget to state the names of these numbers!). (4 marks)

Answer: The bigger number is called the Atomic Mass Number (1 mark) and shows the numbers of protons plus neutrons (1 mark). The smaller number is called the ATOMIC or PROTON number (1 mark) and shows the number of protons. (1 mark)

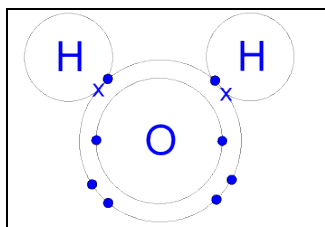
6. Draw and write the electronic configuration for oxygen ($^{16}_8\text{O}$) and hydrogen (^2_1H) (4 marks)

Answer:

Oxygen	Hydrogen
 (1 mark)	 (1 mark)
Electron configuration = 2.6 (1 mark)	Electron configuration = 1 (1 mark)

7. The chemical formula for water is H_2O meaning that for every ONE oxygen atom, there are TWO hydrogen atoms. Show how oxygen and hydrogen bond together by sharing electrons. (2 marks)

Answer:



8. Name the type of bond that forms between atoms when electrons are shared. (1 mark)

Answer: covalent bonds

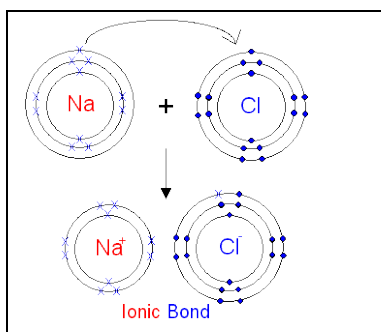
9. The salt in the dirty water that Vanessa drank contains the elements sodium and chlorine. Draw and write the electronic configuration for sodium ($^{23}_{11}\text{Na}$) and Chlorine ($^{35}_{17}\text{Cl}$) (4 marks)

Sodium	Chlorine
 1 mark	 1 mark
Electronic configuration = 2.8.1 (1 mark)	Electronic configuration = 2.8.7 (1 mark)

10. The elements sodium and chlorine combine to form a salt called sodium chloride. Is Sodium chloride an element, mixture or compound? (1 mark)

Answer: compound

11. The sodium and chlorine form sodium chloride by losing and sharing electrons, the chemical formula is NaCl meaning there is ONE sodium atom to every ONE chlorine atom. Use a diagram to show how the sodium and chlorine bond together. (2 marks)



12. Name the type of bond that forms between atoms when electrons are lost or gained. (1 mark)

Answer: ionic bond

Criteria indicators for chemistry:

Outcome 1: Elements, compounds and mixtures

1. Difference between elements, compounds and mixtures
2. One process for separating a mixture

Outcome 2: Atomic structure and position of elements on Periodic Table

1. Internal structure of an atom
2. Difference between atomic number and atomic mass number
3. Write and draw electronic configuration for first 20 elements on Periodic Table

Outcome 3: Ionic and Covalent Bonds

1. Draw diagrams showing how covalent bonds form by atoms sharing electrons
2. Draw diagrams showing how ionic bonds form by atoms losing and gaining electrons



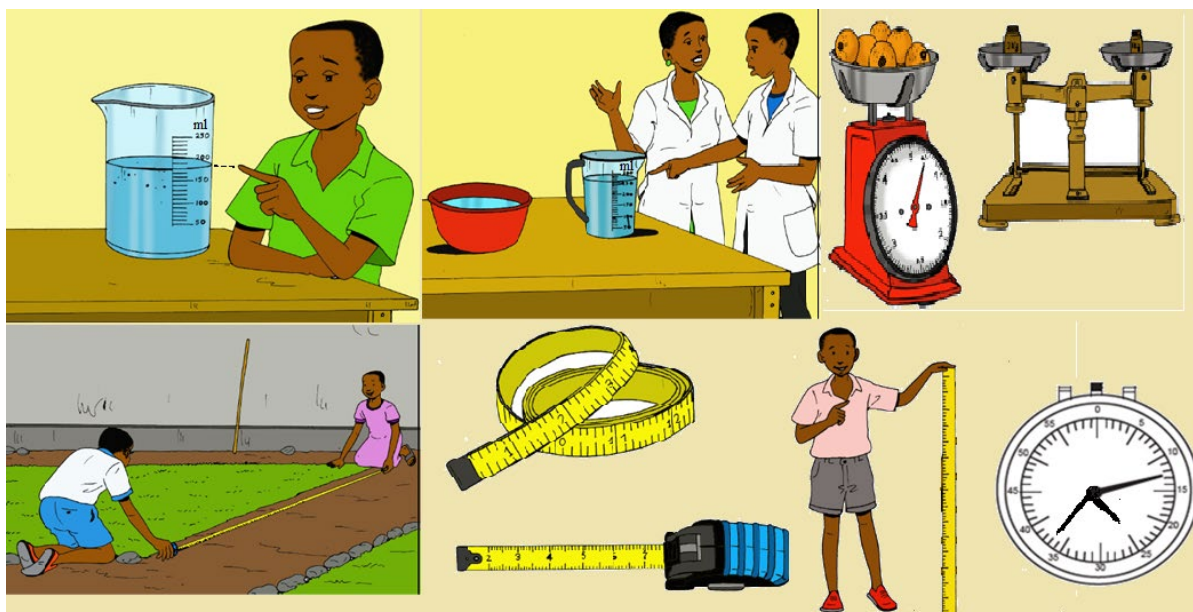
Self-Reflection

1. Ask learners to re-take the self-assessment at the beginning of the unit. They should then fill in the table in the Trainee's Manual to identify their areas of strength, areas for improvement and actions to take to improve.
2. Discuss trainees' results with them. Identify any areas that are giving many trainees difficulties and plan to give additional support as needed (ex. use class time before you begin the next learning outcome to go through commonly identified difficult concepts).

Further Information for the Trainer

1. <https://www.bbc.co.uk/bitesize/guides/zt2hvp4/revision/1>
2. <https://www.bbc.co.uk/bitesize/guides/zt2hvp4/test>
3. <https://www.teachitscience.co.uk/ks4-chemistry/bonding/tags/4296>
4. <https://thescienceteacher.co.uk/covalent-bonding/>
5. <https://www.youtube.com/watch?v=GjmlgyvYID4>
6. <https://thescienceteacher.co.uk/ionic-bonding/>

Learning Unit 4: Apply basic physical concepts at the workplace



Learning Outcomes

By the end of the Learning Unit, trainees will be able to:

- 4.1** Measure physical fundamental and derived quantities at the workplace
- 4.2** Use measuring instruments at the workplace
- 4.3** Use physical laws at the workplace

Learning Unit 4 Self-Assessment

- 1.** Ask trainees to look at the illustration of the learning unit above and in the trainee manual and discuss what they see. What topics do they think this unit will include based on the illustration? Give time for some brainstorming and after share the main topics.
- 2.** Ask trainees to fill out the self-assessment at the beginning of the unit in their Trainee Manual. Explain that the purpose of the self-assessment is to become familiar with the topics in the unit and for them to see what they know or do not know at the beginning. At the end of the unit, they will do a self-reflection, which includes re-taking the self-assessment and identifying their strengths, areas that need improvement and actions to take. The self-assessment is the quick check of the basic knowledge not a test.

Learning Outcome 4.1: Measure physical fundamental and derived quantities at the workplace

	Objectives: By the end of the learning outcome, trainees will be able to: - Differentiate fundamental and derived quantities. - Interpret metric prefixes using names, symbols and factor. - Respect System International (SI) Units in measurement of physical quantities.
	Time Required: 10 hours
	Learning Methodology: Small group work, individual work, brainstorming, self-discovery and large group discussions.
	Materials Needed: • Flipchart papers/chalkboard • Markers/chalk of different colours • Scotch/Masking tape
	Preparation: ☐ Write out two tables in the front of the class, SI base units and SI prefixes. ☐ Prepare a quick lesson on unit conversion if needed.
	Cross Cutting Issues ✓ Standardization culture: emphasize the need to use correct SI Units when measuring physical quantities for purposes of standards in everyday life. ✓ Financial education: emphasize the need to compare units against physical quantities while buying different things.
	Prerequisites: ▶ Notions on unit conversion

Key Competencies:

Knowledge	Skills	Attitudes
1. Explain fundamental and derived quantities	1. Differentiate fundamental and derived quantities	1. Decisive
2. Mention System International (SI) units of physical quantities	2. Relate physical quantities with their SI units	2. Detail-oriented
3. State metric prefixes used in measuring physical quantities	3. Interpret metric prefixes using names, symbols and factor	3. Precise



Steps:



Getting Started: What do we know and where are we going?



Topic 4.1 Task 1:

1. Ask trainees to think about each of the situations and answer the following question:
Which of the following situations can be determined with the guidance of measurements? Support your answer with explanations and mention the physical quantity to be measured if possible. Try to provide the units that you would use to measure each quantity if possible.
 - a. Love between a two people.
 - b. Size of the body.
 - c. Tastiness of a banana
 - d. Brightness of light
 - e. Amount of space occupied by water in a cup.
 - f. Intelligence of a person
 - g. Speed of a car
 - h. The beauty of a painting
2. What are possible physical quantities to be measured in the situations above?
3. Why do we need to have measurements in real life and world of work?
4. Direct the trainees to pair up and discuss among themselves about the situations above. Have some pairs share their responses with the rest of the learners.
5. After the discussion, ask trainees what topic this activity relates to.

6. Introduce the learning outcome and have learners turn to the table of key competencies in their books and review it together. Explain that this learning outcome will focus on measuring physical fundamental and derived quantities.

Physical fundamental quantities are those that are measured in units: length, mass, time, **electric current** temperature, amount of substance, and luminous intensity (power emitted by a light source).

Derived quantities come from the combination of **fundamental quantities**. For example: force, density, volume, momentum etc. They cannot be measured directly. They can only be computed.



Problem Solving Activity



Topic 4.1 Task 2:

1. Make two columns, one labelled “instrument” and the other labelled “quantity”. Ask the trainees to make a list of the different tools they use to measure things. They might respond with a ruler, watch, or scale. Write each response on the board.
2. Ask the trainees what each instrument measures and write in next to the instrument in the “quantity” column.
3. Create a third column labelled “utility at the workplace”. Depending on the technical skill/trade the trainees are pursuing, ask them to list the ways in which they believe they will use the different instruments and quantities in their work.



Topic 4.1 Task 3:

1. Have the trainees try to define the following quantities: mass, length, and time and provide a unit for each of the quantities. The correct responses can be found in **4.1 Key Facts**.
Mass (____):
Length (____):
Time (____):
2. Ask trainees to try to define the following quantities: volume, weight, density, area, and force and provide a unit for each of the quantities.
Volume (____):
Weight (____):
Density (____):

Area (_____):

Force (_____):

3. Ask trainees what the differences are between the quantities in the first group and the quantities in the second group.

Answer: The first group are fundamental qualities. They are the base. The second group are derived quantities in that you need to calculate them using a combination of fundamental qualities (mass, length, time, etc.)

4. Ask for volunteers to share their responses as you move through the questions. For each question, refer them to **4.1 Key Facts** and read together. Address any of the trainee's questions. Give examples as much as possible.



Guided Practice Activity



Topic 4.1 Task 4:

1. Ask the trainees to consider the following workplace related aspects and determine the quantity used to measure the object or thing, whether it is derived or fundamental, its unit and likely prefix you would use to measure the quantity. Use the first aspect as an example. The table is filled in below. However, be sure to let the trainees attempt to fill out the table themselves first.
2. Review their answers together and answer any questions.

Aspect	Quantity	Derived/Fundamental	Unit	Prefix
Determining how long it will take to build a house	Time	Fundamental	Month	None
The amount of water a very large drum can hold	Volume	Derived	Metres Cubed	None
The amount of corn a large restaurant (like Sina's restaurant in Nyirangarama) orders	Weight	Derived	Kilogrammes	Kilo
The neck-size for a shirt one is tailoring	Length	Fundamental	Centimetre	Centi

How much corn per water to mix for cattle feed?	Density	Derived	Kilogrammes per centimetre cubed	Kilo and centi
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Topic 4.1 Task 5:

1. Ask trainees to look at the table below and try to complete it based on the knowledge gained in the previous activities done and information in **4.1 Key Facts**.

Physical quantity	Name of the unit	Symbol of the S I units.
length	metre	m
mass	kilogramme	kg
time	second	s
volume	Cubic metres	m ³
area	Square metres	m ²

2. Ask volunteers to share their responses and answer any questions.



Topic 4.1 Task 6:

1. Look at the table below and try to complete it based on the information in **4.1 Key Facts**.

Answer: Blank spaces should be filled using previous knowledge and **4.1 Key Facts**:

Name	Symbol	Factor		Name	Symbol	Factor
deci	d	10⁻¹		deca	da	10¹
centi	c	10⁻²		hecto	h	10²
milli	milli	10 ⁻³		kilo	k	10 ³
micro	μ	10⁻⁶		mega	m	10 ⁶
nano	n	10⁻⁹		giga	g	10³

2. Ask volunteers to share their responses and answer any questions.



Application Activity



Topic 4.1 Task 6:

Write the following workplace scenario on the board and answer the questions. The correct responses are provided below each of the respective questions.

Scenario: You are working at a cattle farm and your boss tells you that you will need to measure each of the lengths of the corral.

1. You measure the lengths in meters, but the boss wants a longer unit of measure. What unit could you use instead of meters? What is this unit's prefix and what does the prefix represent? Is each length a derived or fundamental quantity?

Answer: You could use kilometres instead of metres. The unit's prefix is kilo which represents 1 000 meters. Length is a fundamental quantity.

2. You measure one length, but the boss wants to know the amount of space inside of the corral. What quantity is he looking for? What is the new unit?

Answer: The boss is looking for area (length x width). Area's unit will be kilometres squared.

Scenario continued: After butchering some meat, the boss asks you to help sell the meat to different clients.

3. When you are selling the meat, what are you measuring? What is the unit (respond with the unit that is used commonly in everyday life)? Is this a derived or fundamental quantity?

Answer: You are measuring the weight of the meat. The unit is newton but in everyday life we use kilogram. This is a fundamental quantity.

4. When selling a larger chunk of meat, say a leg, what is the unit you would use? What is the prefix?

Answer: When selling a larger piece of meat, you would use kilograms. The prefix is kilo.

5. When selling a very small piece of meat, what unit would you use?

Answer: You would use grams.

Scenario continued: A client tells you that he will be ready at 4:30 pm to pick up some meat.

6. What are the units in 4:30 pm? What unit is the largest? What unit is the smallest?
Answer: The units are hours and minutes. Hours are the largest and minutes are the smallest.
7. Is this quantity a fundamental or derived quantity?
Answer: Time is a fundamental quantity.



Points to Remember

- Knowing how to connect units to a quantity is important when presenting information.
- Understanding and using the correct prefixes and units is the first step to measuring quantities.



Formative Assessment

1. What is the difference between a fundamental quantity and a derived quantity?
Provide two examples of each.
Answer: A fundamental quantity does not rely on any other quantities to be measured while a derived quantity is composed of different quantities. Fundamental quantities include time and length. Derived quantities include area and density.
2. Which prefix represents a larger quantity, hecta or centi?
Answer: Hecta represents a larger quantity.
3. If you are given a recipe to make a large quantity of rice for 10 people, how would we measure the rice? What unit would we use?
Answer: We would weigh the rice. We would use kilogrammes to measure the rice.
4. What is the factor for kilo? What number does it represent? How many grams is 3 kilogrammes?
Answer: The factor for kilo is 10^3 . 10^3 represents 1,000. 3 kilograms is equal to 3,000 grams.

Learning Outcome 4.2: Use measuring instruments at the workplace

	Objectives: By the end of the learning outcome, trainees will be able to: - Explain the function of different instruments used in measuring physical quantities - Select appropriate instruments to measure physical quantities - Skilfully use measuring instruments
	Time Required: 10 hours
	Learning Methodology: Small group work, individual work, brainstorming, self-discovery, large group discussions, performing practical exercises
	Materials Needed: - Different coloured markers/chalk - Black/chalkboard
	Preparation: ☐ Flipcharts with clear illustrations of measuring instruments in place. ☐ Required measuring instruments in place. ☐ Different items to measure
	Cross Cutting Issues: ✓ Standardization culture: Emphasize the need to use appropriate instruments when measuring physical quantities for purposes of standards in everyday life. ✓ Financial education: Emphasize the need to compare price against measuring instrument while buying them based on their functionality especially with respect to their specific use.
	Prerequisites: ▶ Notions of geometry such as diameter ▶ Understanding of volume, distance, and mass ▶ Conversion of units, especially centimetres to metres

Key Competencies:

Knowledge	Skills	Attitudes
1. Explain the functions of a metre stick, a ruler, a screw gauge, a Vernier calliper, a balance, an electronic balance and a stopwatch	1. Use a metre stick, a ruler, a screw gauge, a Vernier calliper, a balance, an electronic balance and a stopwatch to measure different physical quantities	1. Skilful
2. Explain the factors needed in selecting best measuring instrument suitable in measurement of quantities	2. Select the most suitable instrument for the corresponding quantity	2. Decisive
3. Describe how the instruments are used in the workplace to measure quantities	3. Analyse how the instruments are used in the workplace to measure quantities	3. Realistic



Steps:



Getting Started: What do we know and where are we going?



Topic 4.2 Task 1:

1. Ask the trainees to consider the following questions and discuss their responses as a large group:
 - a. What is the meaning of the term “measuring instrument”?
 - b. Have you ever used a measuring instrument? In what scenarios?
 - c. How do you select the appropriate measuring instrument to be used in measuring physical quantities?
2. Instruct the trainees to look around the classroom and search for any measuring instrument. Tell them that if they notice any instruments, write down their names and suggest what they are used for. Encourage the trainees to be creative and consider

instruments that they might use to measure something. Some possible answers are in the table below.

Measuring instrument	Purpose (what does it measure?)
<i>Clock/watch</i>	<i>Time</i>
<i>Ruler</i>	<i>Distances</i>
<i>Water bottle</i>	<i>Could be used to measure volume of water</i>

- After the discussion, ask the trainees what topic they think this activity relates to.
- Introduce the learning outcome and then have the trainees turn to the Key Competencies table in their manuals and review it together. Explain that this learning outcome/session will focus on using measuring instruments at the workplace.

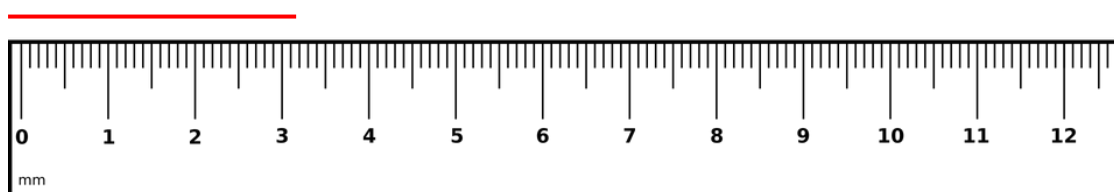


Problem Solving Activity



Topic 4.2 Task 2:

Ask the trainees to observe and read the scale on the following figure given below and try to answer the questions related to it. If possible, use a real metre rule and show them the actual line on the metre rule to give them a clearer concept of the distance.



32

Questions:

- What kind of measuring tool is the figure above?
- What is the length in meters of the red line on the measuring tool above?

Answers:

- Metre rule
- The scale of the metre rule shows that the length of the red line is given by:

³² Image from Pixabay.com; License: <https://pixabay.com/service/license/>

Length of red line = 3.2 cm (centimetres).
Therefore, length of red line = 0.032 m (metres)



Topic 4.2 Task 3:

1. Instruct the trainees to use the following list of instruments to attempt to match each instrument as a means to measure each of the quantities:

Tape measure, weighing balances, plastic tape measure, stopwatch, Vernier calliper

Answers:

- a. The length of a football field: *tape measure*
 - b. The mass of a piece of meat: *weighing balance*
 - c. The circumference of your waist: *plastic tape measure*
 - d. The time someone uses to cover a certain length: *stopwatch*
 - e. The diameter of a small ball: *Vernier calliper*
2. Ask a few volunteers to share their answers and make any clarifications as needed.

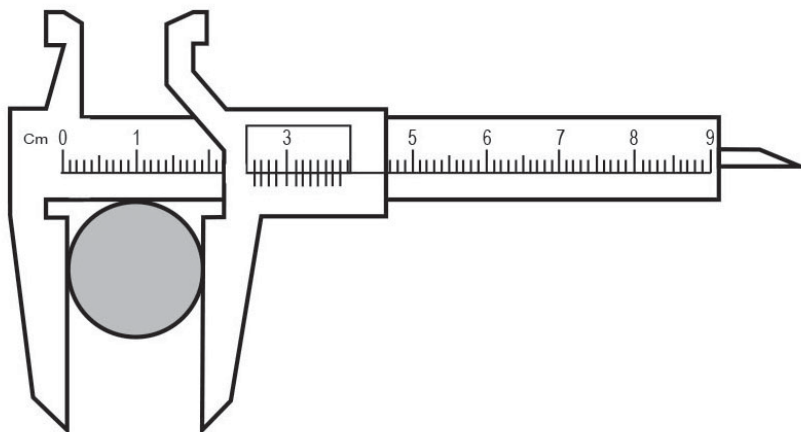


Guided Practice Activity



Topic 4.2 Task 4:

1. Show the trainees how to use the scale of a Vernier calliper to measure the external diameter of the rod. Find a Vernier calliper and a rod and then follow the steps below to practice using a Vernier calliper.
 1. Place the object to be measured between the outside jaws as shown in the figure below. Slide the jaw until they touch and grip the rod.



2. Record the readings on the main scale and the Vernier scale. The main scale reading is the mark on the main scale that is immediately before the zero mark of the Vernier scale.
3. Multiply the Vernier scale reading by 0.01 cm.
4. Add both measurements together, the main scale reading (in cm) and the Vernier scale reading (in cm) to get the diameter of the rod.

Answers:

- For the Vernier shown in Figure above, the main scale reading (MSR) is 2.6 cm. However, to get the second decimal value, we make use of the Vernier scale.
- The Vernier scale mark that coincides exactly with a main scale mark gives the Vernier coincidence (VC).
- In this case, the 6th division coincides with the main scale division. Therefore, the external diameter of the cylindrical object is

$$\text{MSR} + (\text{VC} \times \text{LC}) = 2.6 \text{ cm} + (6 \times 0.01) \text{ cm}$$

$$= 2.66 \text{ cm}.$$

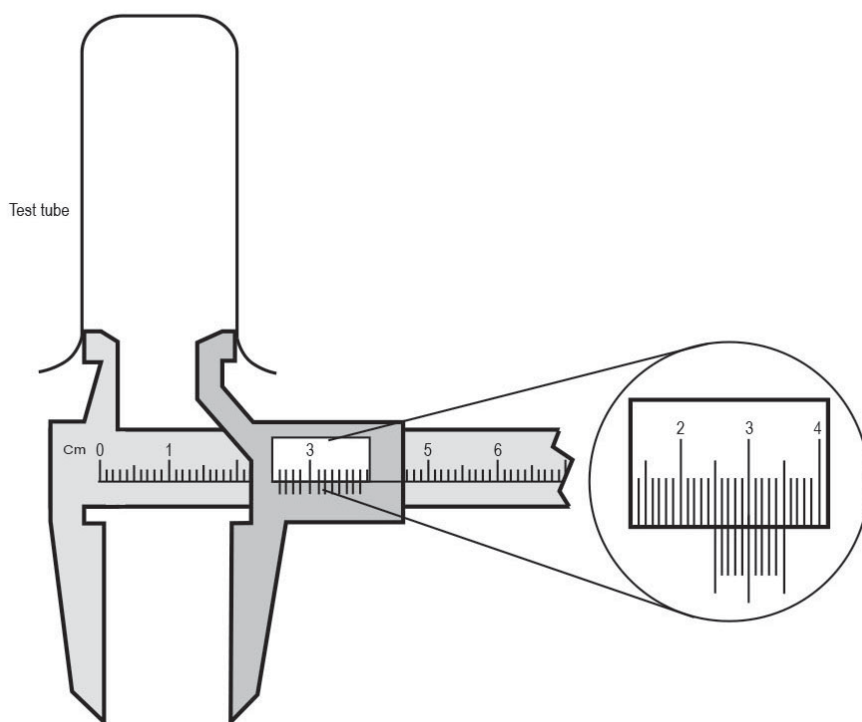
2. Repeat the process as necessary until trainees understand how to use the Vernier calliper. Answer any questions they have.



Topic 4.2 Task 5:

Instruct the trainees to measure and record the internal diameter of a test tube using a Vernier calliper. If you cannot find a test tube, use a different tube where you can measure the internal diameter. If you do not have Vernier callipers, use the figure and the measurements in the figure.

1. Insert the inside jaws of a Vernier callipers into the test tube.
2. Move the sliding jaws until the jaws just touch the inside walls of the test tube as shown in the figure below.
3. Take and record the readings on the main scale and the Vernier scale. Use these readings to determine the internal diameter of the test tube.



Answer:

- We can determine the diameter of the test tube shown in figure above as follows:

The internal diameter of the test tube is given by

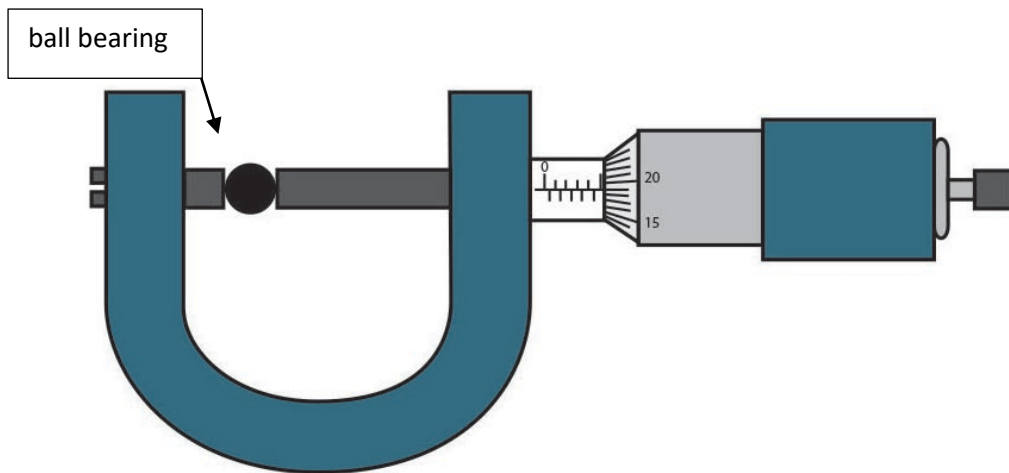
$$\text{MSR} + (\text{VC} \times \text{LC}) = 2.6 \text{ cm} + (2 \times 0.01) \text{ cm} \\ = 2.62 \text{ cm}$$

4. Repeat the process as necessary until trainees are comfortable using the Vernier calliper. Answer any questions they have.



Topic 4.2 Task 6:

1. Using the readings, help the trainees to calculate the following: the diameter of the ball bearing shown in the image below. You may need to provide the trainees with the measurements themselves if they have difficulty reading the numbers on the image. If possible, bring a micrometre screw gauge to class along with a very small item, even a small rock will work. Perform the same task but using the real materials. Assist as needed and review response together.



Answer:

- Main scale reading = 5.0 mm 5.00 mm
- Head scale coincidence = 19 divisions
- Head scale reading = $19 \times 0.01 = 0.19$ mm
- Full reading = $5.0 + 0.19 = 5.19$ mm
- The diameter of the ball bearing is 5.19 mm



Topic 4.2 Task 7:

1. If possible, bring a balancing beam or scale into class and have the trainees measure different objects. Ask the trainees the following questions:
 1. Have you used a scale or balance beam? Have you ever measured how much you weigh, perhaps at the health centre? Do you know how much you weigh?
 2. How do you buy your food? Do you buy it by weighing it first and then paying by the price it weighs?
 3. Have the trainees write out the steps to using a scale. Have them draw the scale they are referring to and explain the scenario in which they use the scale.
2. Ask for a few volunteers to share their responses and answer any questions about using scales.



Topic 4.2 Task 8:

1. Ask the trainees to walk from one point to another, perhaps from one tree to another, but while timing each other.

2. Have them use whatever means of measuring time they have (watch, phone...).
3. Have them do the exercise a couple of times.
4. Tell them that it is important to measure time and record their results so that they can see if they are improving. If they keep track of the time it takes them to do different tasks, they will find that they become quicker and more efficient.



Application Activity



Topic 4.2 Task 9:

Have the trainees go into their communities, especially in their desired workplaces. They should fill out the following form regarding the instruments that the people performing their desired job use. This task can be performed either outside of classroom hours or during classroom hours. Read the form together in class and answer any questions or concerns the trainees may have.

Name of workplace	
Trade or profession	
Measuring instrument or tool and the way it is used	
Measuring instrument or tool and the way it is used	
Measuring instrument or tool and the way it is used	
Measuring instrument or tool	

and the way it is used	
------------------------	--

Ask trainees to share their observations from the visits and discuss the measuring tools they saw being used.



Points to Remember

- It is always very important to follow all recommended safety instructions when using measuring instruments.
- Quality of measurements is an essential step on the way to sensible conclusions.
- Try to be accurate and obtain the true values for the measurements



Formative Assessment

1. Match an instrument with the quantity it measures following the given example in the table below:

Instrument		Quantity measured
1. Meter rule		Time
2. Beam balance		Length
3. Vernier callipers		Small volume
4. Stopwatch		Mass
5. Burette		Diameters of objects

2. Suppose you wish to measure the circumference of a big, oval shaped garden. In order to get the exact values in shortest possible time, we use an appropriate instrument. What is this instrument?
3. If you were baking many cookies at a hotel and they need to be perfect but meanwhile you have to prepare other foods, how would you make sure the cookies bake for the correct amount of time?

4. Imagine that you have killed a pig and are trying to find out how much the meat is worth. You know the price of one kilogram of meat. How would you find out how much the total amount of meat is worth?
5. While vaccinating the cows, you need to give each one a certain amount of liquid in their mouth depending on their size. Suppose you know how much liquid to give each cow. What instrument could you use to measure the liquid and to dispense it in the cows' mouths?

Answer:

Instrument		Quantity measured
1.Meter rule		Time
3.Beam balance		Length
4.Vernier callipers		Small volume
5.Stopwatch		Mass/weight
6.Burette		Diameters of objects.

1. See table above
2. Tape measure
3. Use a stopwatch to keep track of the time the cookies are in the oven.
4. Weigh the meat and multiply it by the price per kilogram.
5. Use a graduated pipette to measure and dispense the correct amount of liquid.

Learning Outcome 4.3: Use physical laws at workplace

	Objectives: By the end of the learning outcome, trainees will be able to: - Explain the process of determining area, volume, density, and weight using formulas - Perform scientific investigation on volume and density - Use measurements to deduce other properties of given bodies
	Time Required: 10 hours
	Learning Methodology: Small group work, individual work, brainstorming, large group discussions, practical demonstration
	Materials Needed: - Flip charts with clear demonstration of numerical problems solved using physical laws - Different coloured markers/chalk
	Preparation: ☐ Prepare flipchart with formulas written on it.
	Cross Cutting Issues: ✓ Standardization culture: When assigning SI Units of distinguished physical quantities, emphasize the importance of standards during measuring physical fundamental and derived quantities at the workplace. ✓ Financial education: Emphasize the importance of measuring density and volume when buying different products, especially food to know the value of the food.

Key Competencies:

Knowledge	Skills	Attitudes
1. Explain the process of determining the volume and area of a solid body of regular and irregular shape	1. Determine the area and volume of a solid body of different real regular and irregular shapes	1. Precise
2. Mention the formula to apply in solving problems on density	2. Perform experimental investigation on density and solve numerical problems on density	2. Investigative
3. Explain the process needed in determining weight of the body	3. Determine the weight of body using the appropriate formula	3. Process-driven



Steps:



Getting Started: What do we know and where are we going?



Topic 4.3 Task 1:

Ask trainees to form small groups and brainstorm and respond to the following questions (answers given here):

1. Label each of the following quantities as either a derived or fundamental quantity:
 - a. Area: *(derived)*
 - b. Density: *(derived)*
 - c. Volume: *(derived)*
 - d. Mass: *(fundamental)*
2. What information would you need to determine each of the following:
 - a. Area: *(length by length or length by height)*
 - b. Density: *(mass and volume of a substance)*
 - c. Volume: *(length by length by length)*
 - d. Mass: *(weight and gravitational field strength)*

3. In what given workplace scenarios do you imagine using each of the following quantities? Provide one scenario for each:
- a. Area: *(area of land in farming, area to build an animal shelter, constructing a table...)*
 - b. Density: *(mixing liquids/gases such as oil and water; building a boat to make sure it floats...)*
 - c. Volume: *(calculating how much liquid will fit in a container)*
 - d. Mass: *(often used interchangeably with weight so when you have to weigh something – products, ingredients, etc.)*

Ask groups to share their answers. Supplement their responses with information from **4.3 Key Facts**.



Problem Solving Activity



Topic 4.3 Task 2:

1. Find a rectangular object in the classroom.
2. Have the trainees measure the area by measuring the length and width of the rectangle's sides.
3. Write the length and width on the chalkboard then have the trainees multiply the two measurements to obtain the area.
4. Ask the trainees what the units are of the measured object. The units should be cm^2 or m^2 .
5. In small groups, ask trainees to find other rectangular objects in the classroom and calculate the area using the same process. Assist as needed.



Topic 4.3 Task 3:

1. Provide the trainees with two cylindrical objects that appear to hold the same amount of liquid but are differing in height and diameter.
2. Ask the trainees which cylinder can hold more liquid.
3. Ask them how they could find out which one holds more liquid. Have them brainstorm and come up with ideas.
4. Try some of their ideas. Perhaps they could fill both of the cylinders up and pour them into containers that are the same. They could also fill one container then add it to the other and see if it overflows or if it does not completely fill the other container.

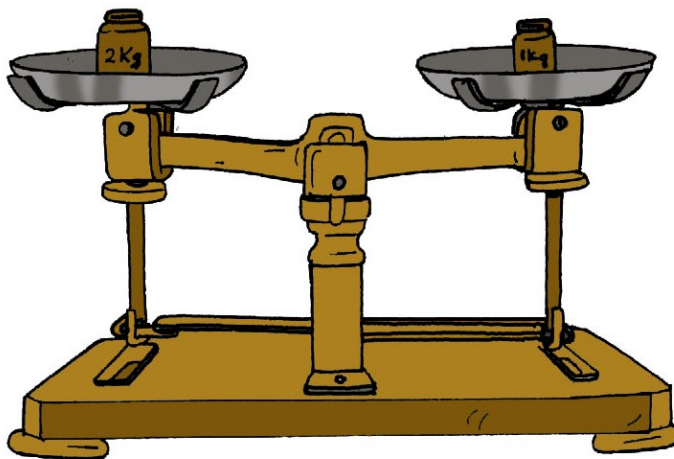
5. Tell them they will learn how to measure the volume of cylinders precisely after a few more activities.



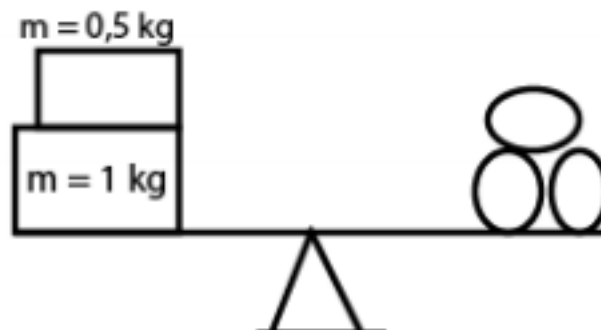
Topic 4.3 Task 4:

1. Ask the trainees if they ever seen a balance beam. Explain to them that a balance beam instrument looks like the picture below. Often, people will use a balance beam to measure food at the market. They should be able to recall the balance beam from the previous Topic as well.

Note to Trainer: If you have access to a balance beam, demonstrate how to use it and give trainees the opportunity to find the mass of objects using it.

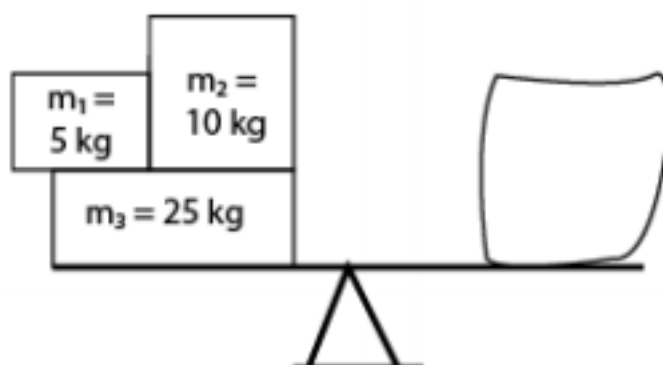


2. The instrument above is a balance beam and is used to measure mass. They come in different forms, but they usually have labelled pieces on one side and the item you want to measure on the other. As pictured above, the labelled weights are on the left side and the right side is for the item you want to measure. You will try to make both sides even and equal so you can find the mass of the item on the right side.
3. Look at the following images and try to determine the mass of the object.



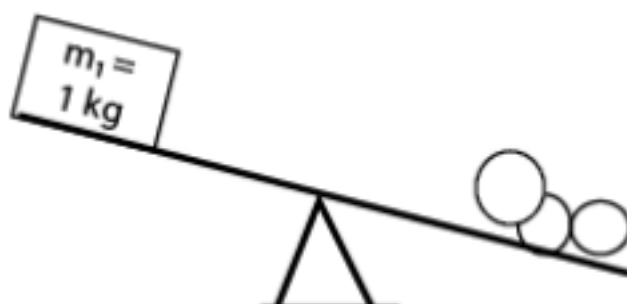
- a. What is the mass of the three onions together on the right side?

Answer: Add up the mass on the left side. The onions have a mass of 1.5 kg.



- b. What is the mass of the bag of rice on the right side?

Answer: Add up the mass on the left side. The bag of rice has a mass of 40 kg.



- c. What is the mass of the three onions on the right side?

Answer: We cannot know the mass of the onions because the scale is not equal on both sides. We cannot say that the mass is 1 kg. The mass is heavier than 1 kg, but we cannot say what the mass is exactly.

4. If you have access to a balance beam, ask trainees in small groups to find objects in the classroom and measure their mass using the balance beam.
5. Answer any questions about how to measure mass and how to use a balance beam.



Topic 4.3 Task 5:

1. Choose two objects that are the same size but made of different materials, one that is lighter such as a sponge and another that is heavier such as a rock. You can even choose a smaller, heavier rock and a larger, but lightweight, sponge or similar material as long as it is light.
2. Ask the trainees what the difference is. How can an item be smaller than another and at the same time heavier?
3. Ask the trainees to try to fill in the blank. Even though two objects have the same volume, the object that weighs more than the other has more mass.
4. Explain to the trainees that the object with more mass but the same volume, is *denser* than the other.

5. Read **4.3 Key Facts** with the trainees as a large group. Address any of the trainees' any confusion or concerns.



Guided Practice Activity



Topic 4.3 Task 6:

1. Using the formulas and information from **4.3 Key Facts**, solve the following problems:
- a. The dimensions of the top of a small coffee table are 40 cm by 30 cm. Calculate the area of the top of the table in (i) m^2 (ii) mm^2 .

Answer:

Walk the trainees through the following steps:

Read and prompt the trainees with the questions

What information are you given?

Length of a small coffee table = 40cm

Width of a small coffee table = 30cm

Plan and solve

What quantity are you trying to calculate?

The area of a small coffee table in (i) m^2 and (ii) mm^2 =?

What formula contains the given quantities and the unknown quantity?

area = Length $\times$ width

Perform the calculation.

(i) area = $L \times w \Leftrightarrow$ area = $40 \text{ cm} \times 30 \text{ cm} = 1200 \text{ cm}^2$

$$\text{area} = \frac{1200}{10\,000} \text{ m}^2 = 0.12 \text{ m}^2$$

(ii) area = $L \times w = 40\text{cm} \times 30\text{cm} = 1200\text{cm}^2$

area = $1200 \times 100\text{mm}^2 \Leftrightarrow$ area = $120\,000\text{mm}^2$

- b. A small block of wood floats on water. It has a mass of 200g and a volume of 250 cm^3 . What is the density of the wood?

Answer:

Read and prompt the trainees with the questions

What information are you given?

Mass of block = 200 g

Volume of block = 250 cm^3

Plan and solve

What quantity are you trying to calculate?

The density of the block =?

What formula contains the given quantities and the unknown quantity?

$$\text{Density} = \frac{\text{Mass}}{\text{Volume}}$$

Perform the calculation.

$$\text{Density} = \frac{\text{Mass}}{\text{Volume}} \Leftrightarrow \text{Density} = \frac{200g}{250cm^3} \Leftrightarrow \text{Density} = \mathbf{0.80\ g/cm^3}$$

Look back and check

Does your answer make sense?

Explain to the trainees that because the density is lower than $1.0\ g/cm^3$ (the density of water), which makes sense because the block can float.

- c. The density of mercury is $13.6\ g/cm^3$. What volume will have a mass of 200 g.

Answer:

Read and understand

What information are you given?

Density of mercury = $13.6\ g/cm^3$

Mass of mercury = 200 g.

Plan and solve

What quantity are you trying to calculate?

Volume of Mercury =?

What formula contains the given quantities and the unknown quantity?

$$\text{volume} = \frac{\text{mass}}{\text{density}}$$

Perform the calculation.

$$\text{volume} = \frac{200g}{13.6g/cm^3} \Leftrightarrow \text{volume} = 14.7cm^3$$

Look back and check

Does your answer make sense?

Because $\text{volume} \times \text{density} = \text{mass}$ you can check to see if the volume is correct for a mass of 200 g

$$14.7cm^3 \times 13.6 \frac{g}{cm^3} = 199.92\ g \cong 200\ g$$

- d. What mass of gold has a volume of $2.5\ cm^3$? (Take the density of gold as $19.3\ g/cm^3$).

Answer:

Read and understand

What information are you given?

Density of gold = $19.3\ g/cm^3$

volume of gold = 2.5 cm^3

Plan and solve

What quantity are you trying to calculate?

Mass of gold =?

What formula contains the given quantities and the unknown quantity?

$mass = density \times volume$

Perform the calculation.

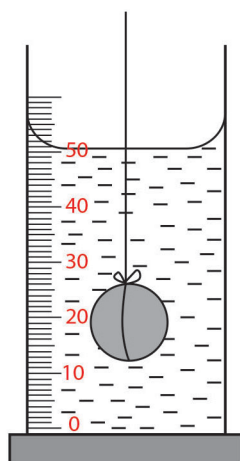
$mass = 19.3 \text{ g/cm}^3 \times 2.5 \text{ cm}^3 \Leftrightarrow mass = 48.25 \text{ g}$

2. Clarify any questions trainees have on using the formulas to calculate area, volume, density and mass. Give them more examples to practice if there is time.



Topic 4.3 Task 7:

1. Explain to trainees that you are going to demonstrate how to measure the volume of a solid object using a measuring cylinder, metre rule, marble and water. If possible, use an actual measuring cylinder and a rock or object that has an irregular shape. Walk through the steps with the trainees:
 1. Partly fill a measuring cylinder with water and record the initial volume of the water, V_1 .
 2. Carefully lower the marble into the water in the measuring cylinder and record the new volume of the water, V_2 .



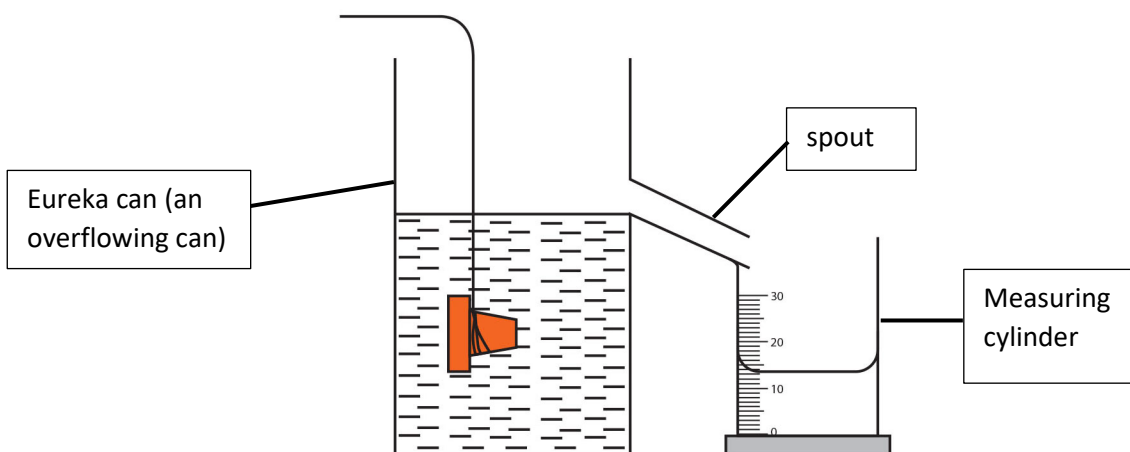
Volume by displacement method.

3. Find the volume of the water displaced, ($V_2 - V_1$). The answer will equal the volume of the object you placed in the water.
2. Ask trainees to form small groups and repeat the process using a different object. Assist each group as needed.
3. Ask groups to share their results. Before giving the volume, the other groups should first guess the volume of the object.



Topic 4.3 Task 8:

1. Explain to trainees that similar to the previous activity, it is possible to measure the volume of any irregularly shaped solid using a Eureka can, water and measuring cylinder. Try to make and use a Eureka can (ex. Make hole in plastic container insert a small tube such as an empty Bic pen and glue around the edges.) and use another irregularly shaped object such as a rock.
2. Explain that you will take them through the following steps and then they will find other irregularly shaped objects and repeat the process.
 1. Fill a Eureka can with water until some of it overflows through the spout.
 2. Once the overflow stops, put the measuring cylinder at the mouth of the spout.
 3. Tie the irregular solid with a string and lower the solid carefully into the can. Make sure the solid is completely immersed.
 4. Collect and measure the volume of the water displaced as shown in the figure below.



Measuring volume using a Eureka can

Hint: From task above, it is noted that the volume of the solid is equal to the volume of the water displaced.

3. Assist the groups as they try the process with another object.



Application Activity



Topic 4.3 Task 9:

1. Explain to the trainees that this activity will require them to go into their community. You may instruct the trainees to perform this activity during or outside of class time.
2. Explain the following to the trainees: depending on your specific specialty, go into your community and ask the different workers how they use different physical laws or concepts (e.g. mass, density, volume...). The responses they give will vary depending on their trade or profession. Use the following table as a guide.

Name of workplace	
Trade or profession	
Do they use mass at the workplace? How do they use mass? Likewise, if not mass, how do they use weight?	

Do they use volume at the workplace? How do they use volume?	
Do they use density at the workplace? How do they use density?	
How do they measure volume of the substances or materials they use? Do they do any calculations?	
Do they do any calculations to measure any physical qualities of objects? Which ones? What formulas do they use?	

- After the visit, ask trainees to share their findings. Write responses on the board so everyone can see the different ways in which these physical concepts play out in the workplace.



Points to Remember

- Units of different quantities should be used when corresponding in the same calculation.
- Density is a very important property of every material in our environment just because it is used to compare materials.
- Even if you do not use density in the workplace immediately, it is an important concept that applies to other domains as well such as the number of animals per square hectare



Formative Assessment

1. Complete the table below and fill in the blanks. Use the formula for density to find the missing measurement for each of the materials.

Material	Mass (g)	Volume (cm ³)	Density (g/cm ³)
Steel	160	20	
Wood	150	150	
Lead	110		11
Glass		50	2

2. A room measures 3 metres by 4 metres by 5 metres. Calculate:
 - a. The volume of the room in cubic metres.
 - b. The mass of air in the room given that the density of air = 1.2kg/m³.
3. Complete the table below and fill in the blanks. Use the formula for density to find the missing measurement for each of the objects.

Object	Volume	Mass	Density
P	200 cm ³	1600 g	
Q	10 cm ³	230 g	
R		800g	8 g/cm ³
S	120cm ³		0.5 g/cm ³

- a. Which two out of P, Q, R, and S could be the same material, e.g. have the same density?
- b. Which one takes up most space, e.g. has the greatest volume?
- c. Which one would be heaviest to lift e.g. has the largest mass?

4. Name a couple of methods for measuring the volume of an irregularly shaped solid.

Answers:

1. Complete the table below and fill in the blanks. Use the formula for density to find the missing measurement for each of the materials.

$$\text{Density} = \frac{\text{Mass of the substance}}{\text{Volume of the substance}}$$

Material	Mass (g)	Volume (cm ³)	Density(g/cm ³)
Steel	160	20	8
Wood	150	150	1
Lead	110	10	11
Glass	100	50	2

2. A room measures 3 metres by 4 metres by 5 metres. Calculate:
From the dimensions given, the volume of a room, $V = 3 \text{ m} \times 4 \text{ m} \times 5 \text{ m}$

- a. $V = 60 \text{ m}^3$
- b. Mass = ?, $V = 60 \text{ m}^3$ and density = 1.2 kg/m^3
Since mass = density x volume
Mass = $1.2 \text{ kg/m}^3 \times 60 \text{ m}^3$, mass = 72 kg

3. Complete the table below and fill in the blanks. Use the formula for density to find the missing measurement for each of the objects.

Object	Volume	Mass	Density
P	200 cm ³	1600 g	8 g/cm ³
Q	10 cm ³	230g	23 g/cm ³

R	100 cm ³	800 g	8 g/cm ³
S	120 cm ³	60 g	0.5 g/cm ³

- a. Objects P and R could be the same material
- b. Object P takes up the most space
- c. Object P has the largest mass.

4. Name a couple of methods for measuring the volume of an irregularly shaped solid.

To measure the volume of an irregularly shaped solid one can use a graduated cylinder, or a Eureka can.



Summative Assessment

1. Write the scenario below on the board/flipchart.
2. Read the scenario together.
3. Explain to the trainees they will be assessed on their ability to use what they have learned in the unit to address the following situation and questions that follow.
4. Provide the trainees with the instructions and questions. Give them ten minutes to prepare.
5. You will walk through each of the questions prompting each of the trainees for responses.
6. After the trainees respond to the questions from the scenario, provide them with a grade of Yes or No meaning that they either did or did not demonstrate the specific indicator. If the trainee scores 5 or higher, they are deemed competent.

Scenario: You need to buy cleaning supplies. Answer each of the following questions regarding the details of the cleaning supplies.

- a. The supplies have several specifications on the label which are listed below. Determine **the type of quantity**, whether these are **fundamental or derived quantities**, and the **unit** used for i – iv.

- i. Mix the 1 litre of the cleaning solution with 2 litres of water
 - ii. Measure the mass of the mixture to ensure the mass is 4 kg per 3 litres
 - iii. Let the solution rest for 15 minutes before using
 - iv. Use 300 millilitres of solution per metre squared of surface to clean
- b. Once you have begun using the solution you are ready to clean a rectangular shaped floor.
 - i. What instrument would you use to measure the size of the floor?
 - ii. What instrument would you use to measure the volume of liquid once you know the amount of space to clean?
 - iii. How could you measure the mass of the cleaning solution?
 - iv. What instrument could you use to time the amount of time to wait while the solution rests after being mixed?
- c. If the measurements of the floor measure 5 metres by 3 metres, what is the area of the floor?
- d. You have mixed the solution and find the mass is 4 kg and the volume is 3 litres, what is the solution's density?

Answers:

- a. *Answers to (a)*
 - i. Cleaning solution and water. We are measuring volume. Volume is a derived quantity. The unit is the litre.
 - ii. We are measuring mass. Mass is a fundamental quantity. The unit is the kilogramme.
 - iii. We are measuring time. Time is a fundamental quantity. The unit is the minute.
 - iv. We are measuring volume and area. Both are derived quantities. The units are millimetres and metres.
- b. *Answers to (b)*
 - i. Tape measure/metre rule
 - ii. A container with a known amount of volume such as a 2-litre bottle
 - iii. A balance
 - iv. A stopwatch
- c. Area = length x width so $5\text{m} \times 3\text{m} = 15\text{ metres}^2$

d. $Density = \frac{Mass\ of\ the\ substance}{Volume\ of\ the\ substance}$

4kg/3litre or 1.33 kg/litre

Checklist	Score	
	Yes	No
Indicator 1: Identifies the correct units, type, and classification of different quantities		
Correctly identifies the unit for each quantity		
Correctly classifies each and every quantity as either a fundamental or derived quantity		
Determines the type of quantity (e.g. time, mass, density, etc.)		
Indicator 2: Determines the correct instrument to measure each of the quantities		
Describes the correct instrument to measure each of the quantities		
Indicator 3: Applies the physical laws to the workplace		
Correctly calculates the area and density		
Provides the area and density with their correct units		



Self-Reflection

1. Ask learners to re-take the self-assessment at the beginning of the unit. They should then fill in the table in the Trainee's Manual to identify their areas of strength, areas for improvement and actions to take to improve.
2. Discuss trainees' results with them. Identify any areas that are giving many trainees difficulties and plan to give additional support as needed (ex. use class time before you begin the next learning outcome to go through commonly identified difficult concepts).

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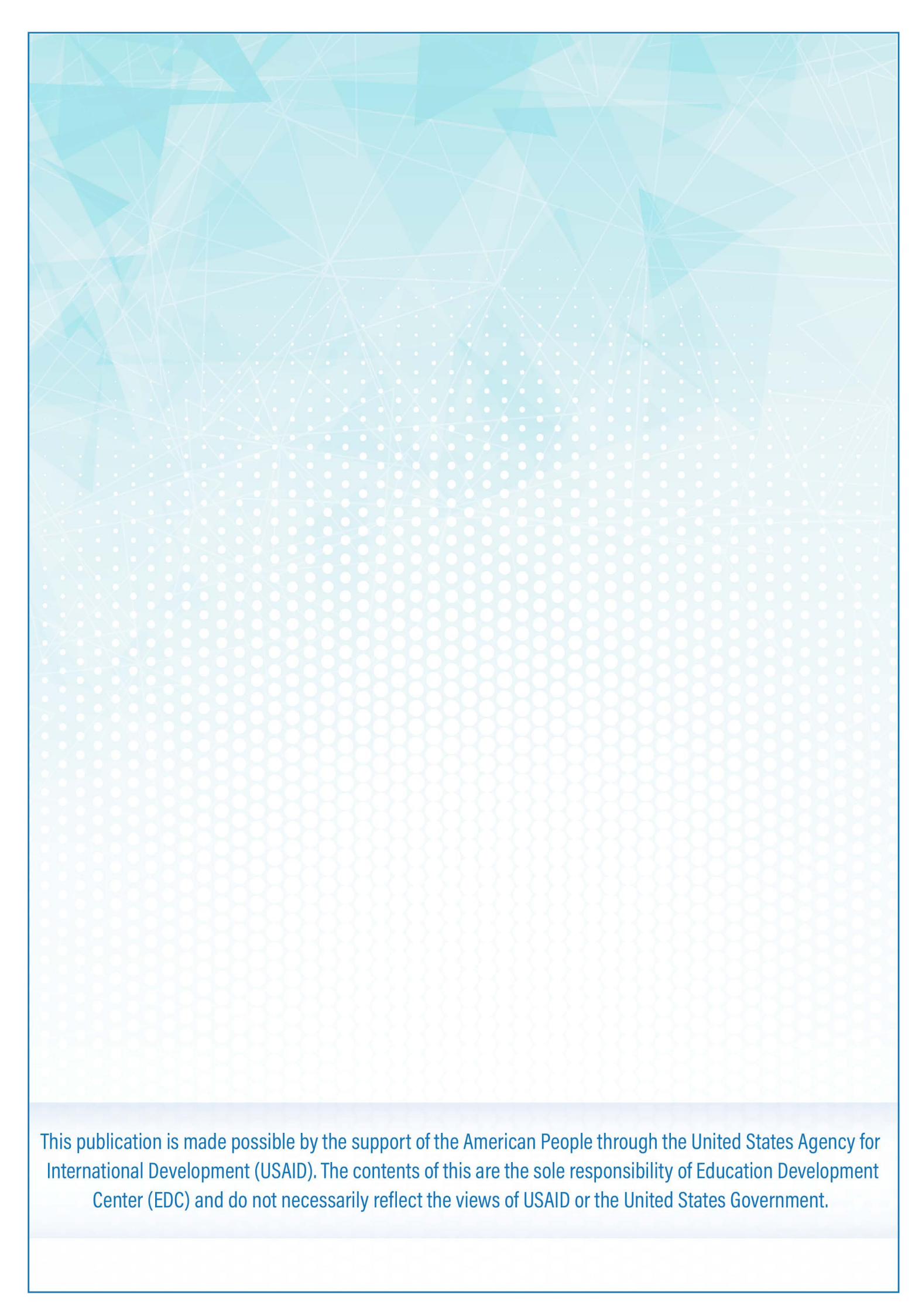
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