UNIT 1
Force, Motion, and Energy

Suggested time allotment: 8 to 10 hours

Unit 1
MODULE
1 FORCES AND MOTION

Overview

In Grade 7, you described an object's motion in terms of displacement, speed or velocity, and acceleration. You performed activities wherein you interpreted or created visual representations of the motion of objects such as tape charts and motion graphs. The concepts were arrived at by studying examples of uniform motion or objects moving in straight line at constant speed. Then you were also introduced to non-uniform motion where the object covers unequal distances or displacements at equal intervals of time. When a jeepney starts moving, it speeds up. When a jeepney nears a stop sign, it slows down. The jeepney is covering different displacements at equal time intervals and hence it is not moving at a uniform velocity. In other words, the jeepney is accelerating.

Most of the motions we come across in our daily life are non-uniform and the primary cause of changes in motion is FORCE. In this module, you will learn about the effects of force on motion. Newton's Three Laws of Motion – the central organizing principle of classical mechanics – will be presented and applied to real-life situations.

At the end of Module 1, you will be able to answer the following key questions:

Do forces always result in motion?

What are the conditions for an object to stay at rest, to keep moving at constant velocity, or to move with increasing velocity?

How is force related to acceleration?

In the lower grades, you learned that an object can be moved by pushing or pulling. In physics, this push and pull is referred to as *force* (F). Consider a ball on top of a table as shown in Figure 1. If someone pushes the ball, it will move or roll across the surface of the table (Figure 1a). And when it is again pushed in the direction of its motion, it moves farther and even faster (Figure 1b). But when you push it on the other side instead, opposite to the direction of its motion, the ball may slow down and eventually stop (Figure 1c). Lastly, when you push it in a direction different from its original direction of motion, the ball also changes its direction (Figure 1d). Force therefore can make objects move, move faster, stop, or change their direction of motion. But is this always the case? Can force always bring about change in the state of motion of an object?

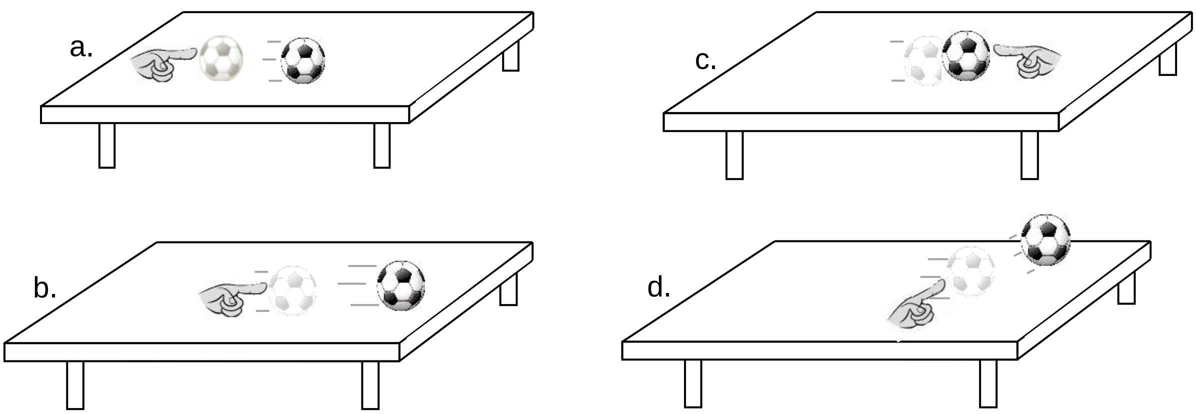


Figure 1. Effect of force on an object

Balanced and Unbalanced Forces

An object may be acted upon by several forces. For example, an object may be pushed and pulled in different directions at the same time. To identify which of these forces would be able to cause change in the motion of the object, it is important to identify all the forces acting on it.

To accurately describe the forces acting on an object, it is important for you to be familiar first with the following terms: *magnitude, direction, point of application,* and *line of action*. Forces are described in terms of these properties. **Magnitude** refers to the size or strength of the force. It is commonly expressed in Newton (N). Consider the diagram in Figure 2 showing a force, represented by the arrow, acting on a ball. The direction of the arrow indicates the **direction** of the force while the length of the arrow represents the relative magnitude of the force. If the force applied on the ball is doubled, the length of the arrow is increased two times. The **line of action** is the straight line passing through the **point of application** and is parallel to the direction of the force.

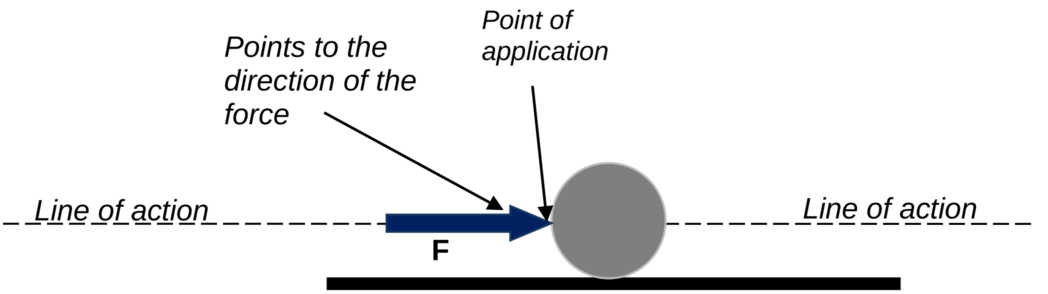


Figure 2. Force acting on a ball

Activity 1
Forces on objects at rest

Objectives:

After performing this activity, you should be able to identify the forces acting on an object at rest.

Materials:

pen	pair of scissors
string	book

Procedure

Situation 1

1. Hang a pen by a piece of string as shown in Figure 3a.

Q1. Is the pen at rest or in motion?

Figure 3a. Hanging pen

Q2. Are there forces acting on the pen? If yes, draw the forces. You may use arrows to represent these forces.

2. Cut the string with a pair of scissors.

Q3. What happens to the pen? What could have caused the pen's motion?

Situation 2

1. Place a book on top of a table as shown in Figure 3b.

Q4. Is the book at rest or in motion?

Q5. Are there forces acting on the book? If yes, draw the forces acting on the book.

2. Let one member of your group push the book in one direction and another member push it in the opposite direction at the same time with the same amount of push (force).

Q6. Did the book move? How will you make the book move?

Figure 3b. Book on a table

In the situations above, both the pen and the book are at rest. But this does not mean that there are no forces acting on them. So what causes them to stay in place? Consider the next activity.

Activity 2
Balance of forces

Objectives:

After performing this activity, you should be able to:

1. examine the conditions when two forces balance, and

2. explain the effect of balanced forces on the state of motion of an object.

Materials:

4 sets spring balance
1 piece of sturdy cardboard
threads

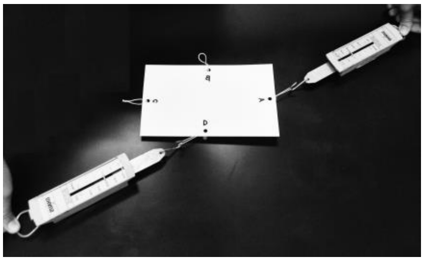


Figure 4

Procedure:

1. Bore four holes around the cardboard as shown. Label the holes A, B, C, and D.

2. Attach threads to the holes.

3. Attach a spring balance to thread A and another one to thread D. Hold the cardboard to keep it still. Pull the balances along the same line such that when released, the cardboard remains at rest.

4. When the cardboard is at rest, examine the magnitudes and directions of the two forces by reading the spring balance.

5. Draw the line of action of the forces acting on the cardboard. Extend the lines until they intersect. Mark the point of intersection and draw arrows starting at this point to represent the forces acting on the cardboard.

6. Repeat steps 3 to 5 for pair B and C.

Q7. When the cardboard is at rest, how do the magnitudes and directions of the pair of forces acting on it compare?

7. Now here is a challenge. Find out the directions of all the forces such that when all the threads were pulled with the same amount, the cardboard will not move or rotate when released.

Q8. If you draw the lines of action of all the forces acting on the board and extend the lines, what will you get?

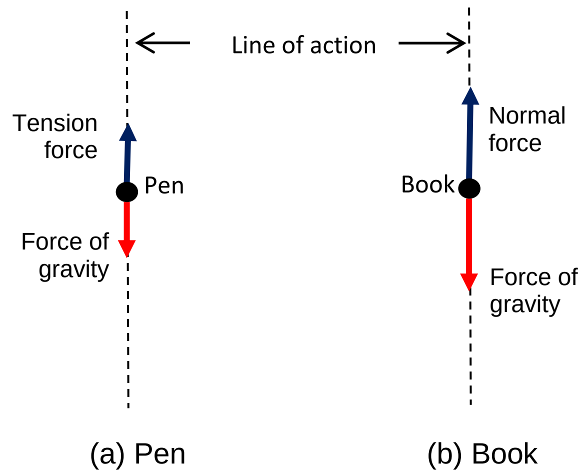


Figure 5: Force diagram

The diagram in Figure 5 shows the forces acting on the a) pen and b) book in Activity 1. You learned in lower grades that all objects fall down because gravity pulls on them towards the center of the earth. But what makes the pen and the book stay at rest? The pen stays in place because of another force that acts on it that is supplied by the string which we refer to in physics as tension force (T). The book, on the other hand, stays at rest because of the upward push exerted on it by the table which we refer to as normal force (F_n). Both the tension force and normal force counteract the pull of gravity (F_g) that acts on the objects. Study the diagram. How do the lengths of the arrows in each case compare? How do the magnitudes and directions of the pair of forces compare?

In both cases, we can infer that the objects remained at rest because the forces acting on them are equal in magnitude and in opposite directions and they lie along the same line of action (Figure 5). The forces are **balanced**. This was also demonstrated in Activity 2. Also, if you try out step 7 in Activity 2, you will find that the lines of action of the four forces intersect through a single point. This also explains why the body does not move or rotate.

Unbalanced Forces

If you cut the string connected to the pen, the pen will fall. Or if you push the book on one side across the table, the book will move but will not continue moving if you don’t continuously push it. The pen falls down because there is no more force acting on it to counteract the pull of gravity. The book moves because of the push that you applied. In other words, the forces acting on these objects are no longer balanced. If an object initially at rest is under an unbalanced force, it moves in the direction of the unbalanced force.

How about if the object is already in motion, how will the unbalanced force affect its motion?

Place a ball on the desk then push it gently to one side. Observe the motion of the ball as it rolls down the desk. What makes the ball stop rolling after sometime? Again, you need to identify the forces acting on the ball. You can see in Fig. 6 that the force of gravity and the normal force are again acting on the ball. But these forces are balanced, and so the ball stays on top of the desk. However, there is another force that acts on the ball along the horizontal line or along the force that set the ball in motion. Do you still remember your lesson on friction in the lower grades? You learned that friction is a force that acts between surfaces that are in contact with one another. Friction in general acts opposite the direction of motion. In the case of the rolling ball, the frictional force acts between the surfaces of the ball and the desk and slows down the motion of the ball.

As the ball rolls to the right as shown in Figure 6, friction acts to the left to retard its motion. Since you did not push the ball continuously there is no force present to balance the force of friction. So the ball slowed down and eventually stopped.

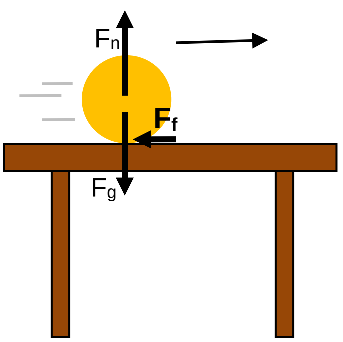


Figure 6. Forces acting on a rolling ball

Again, due to the unbalanced force, the object changes its state of motion hence we say that it accelerates. Note that acceleration is not just an increase in velocity, but also a decrease in velocity.

Combining Forces

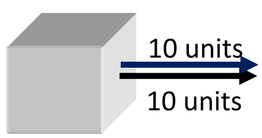
When we combine or add forces to determine the net or unbalanced force, we will limit our discussion to those forces which act along the same line of action. The algebraic signs + and – are used to indicate the direction of forces. Unlike signs are used for forces acting in opposite directions, like in the case of the book lying on the table. The force of gravity (F_g) and normal force (F_n) are assigned opposite signs - F_n is given a positive (+) sign while F_g is given a negative (-) sign. If both F_g and F_n are given a magnitude value of 3 units, then the net force along this line (vertical) will be:

$$
\begin{aligned}
F_{net} &= F_n + F_g \\
&= 3 \text{ units} + (-3 \text{ units}) \\
&= 0
\end{aligned}
$$

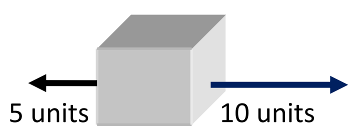
If the sum of the forces equate to zero, they are considered **balanced**. If the algebraic sum is not equal to zero, the forces are not balanced. The non-zero sum is the net or unbalanced force. This unbalanced or net force would cause a change in a body's state of motion.

<u>Concept check:</u>

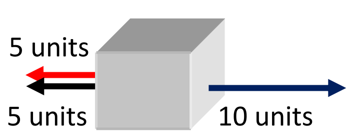
Study the illustrations and answer the questions that follow.



1. A boy and a girl are pulling a heavy crate at the same time with 10 units of force each. What is the net force acting on the object?



2. What if the boy and the girl pull the heavy crate at the same time in opposite directions with 10 units and 5 units of force respectively, what will be the net force on the object? Will the object move? To what direction will it move?



3. Suppose another girl pulls the heavy crate in with 5 units of force in the same direction as the girl, what will be the net force that will act on the object? Will the object move?

Newton's Three Laws of Motion

The principles behind Newton's laws of motion are very significant in understanding the motion of objects in our universe. Their applications are all around us. Understanding these laws therefore helps us understand why the things around us move or behave the way they do.

Newton's First Law of Motion: Law of Inertia

You learned that if the forces acting on an object at rest are balanced or if their algebraic sum equate to zero, the object stays at rest. This illustrates Newton's

First Law of Motion, a principle that was primarily based on the works of Galileo. The following examples will help you understand this principle better.

Activity 3
Investigating inertia

Objective:

At the end of this activity, you should be able to demonstrate Newton's first law of motion.

Materials:

empty glass	5-peso coins (5 pcs or more)
cardboard	plastic ruler
1 peso coin	

Procedure

Coin Drop

1. Arrange the setup as shown in Figure 7.

2. Slowly pull the cardboard with your hand and observe what happens.

3. Arrange again the setup as shown. This time, quickly flick the cardboard with your finger. Observe again what happens.

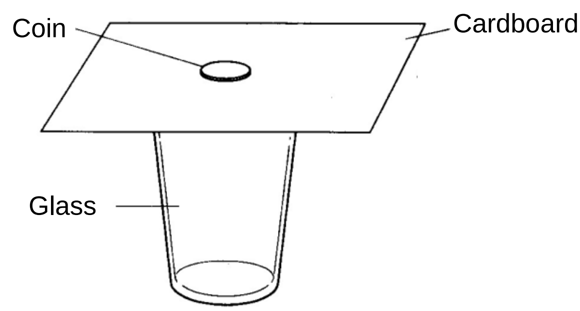


Figure 7. Cardboard and coin

Q9. What happens when you slowly pulled the cardboard? Explain.

Q10. What happens when you flicked the cardboard? Explain.

Stack of Coins

4. Stack the coins on a flat level surface.

5. Quickly hit the coin at the bottom with the edge of the ruler.

Q11. What happens when you hit the coin at the bottom? Why is this so?

The examples above demonstrate the property of an object to resist any change in its state of motion. In physics, this property is known as **inertia**. The coin dropped into the glass because it was trying to remain in its state of rest. How about in the second example? How will you explain the behavior of the coins when one of them was hit with an edge of a ruler?

Measure of Inertia

All objects have the tendency to resist changes in their state of motion or keep doing what they are doing. However, changing a body's state of motion depends on its inertia. A more massive object which has more inertia is more difficult to move from rest, slow down, speed up, or change its direction.

Newton's first law states that *an object at rest will stay at rest or an object in motion will stay in motion and travel in straight line, as long as no external net force acts on it*. The object will change its state of motion only if there is unbalanced or net force acting upon it.

> ***Law of Inertia***
>
> *A body will remain at rest or move at constant velocity unless acted upon by an external net or unbalanced force.*

Newton's Second Law of Motion: Law of Acceleration

You learned that when the velocity of a moving body changes, we describe the motion as one with acceleration. Is there any relationship between acceleration and any unbalanced force that acts on the body? Find out in the next activity.

Activity 4
Force and acceleration

Objective:

After this activity, you should be able to describe how the net force acting on an object affects its acceleration.

Procedure:

Consider this situation below:

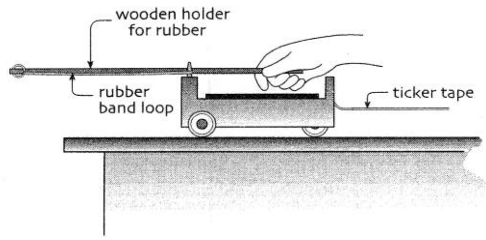


Figure 8. Cart pulled by rubber bands

A group of students conducted an experiment to determine the relationship between the force acting on the object and its acceleration. They used identical rubber bands to pull the cart as shown in Figure 8. They varied the number of rubber bands to vary the force acting on the cart. They started with 1 rubber band, then with 2, 3, and 4 rubber bands, making sure that they stretched the rubber bands to the same length every time they pull the cart. They used a ticker tape timer to determine the acceleration of the cart. A ticker tape was connected to the cart such that when the cart was pulled, the paper tape will be pulled through the timer. And as the paper tape was pulled through the timer, small dots are formed on the tape.

Starting with the tape for 1 rubber band, they marked the first clear dot and every 6^{th} dot thereafter and cut the tape along these points (Figure 9). Then they pasted the strips side by side in order on a graphing paper to produce the tape chart for F=1 unit. They did the same for the other tapes to produce tape charts for F=2 units, F=3 units, and F=4 units.

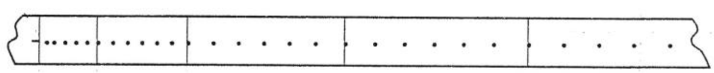


Figure 9: Sample tape

A. Tape chart analysis

1. Obtain from your teacher the copies of the tape charts produced by the students for the 4 runs.

Q12. Compare the charts. What similarities and differences have you noticed among them?

The length of strip in each chart represents the total distance travelled by the cart over a time interval of 0.10 seconds. Recall that the total distance travelled over a unit time gives the average velocity of the moving body, or speed when travelling in straight line. Hence, *each strip represents the average velocity of the cart over a time interval* of 0.10 seconds.

2. Examine the tape chart for F=1 unit.

Q13. What does the increase in the lengths of the strips suggest? What can you say about the motion of the cart - is it moving in uniform motion or is it accelerating? Is this also true with the other runs?

Q14. How do you compare the increase in length of the strips in F= 1 unit? What does this tell you about the change in the velocity of the cart? Is this also true with the other tape charts?

Q15. How do you compare the increase in length of the strips among the four tape charts? Which tape chart shows the greatest increase in the length of the strips? Which tape chart shows the least increase in the length of the strips?

3. Draw a line that passes through all the dots at the ends of the strips in F=1 unit. Do the same for the other tape charts.

Q16. Describe the line formed. Does the same pattern exist for the other tape charts?

B. Quantitative analysis

You can also use the tape chart to compute for the average velocity (v_{ave}), change in velocity (Δv), and acceleration (a) of the cart for each run. Work only on the tape chart assigned to your group. Other groups will be working on the other charts. You may follow the simple instruction below.

4. Label each strip 1,2,3,4, and 5 as shown in Figure 10.

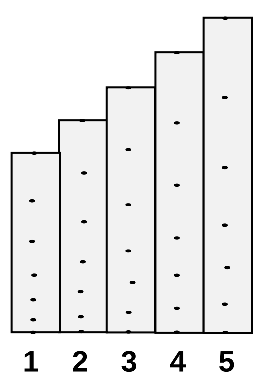


Figure10: Sample tape chart

5. Compute for the average velocity of the cart over each time interval by measuring the length of the strip and dividing it by the time covered to travel such distance. Example, if the length of the strip is equal to 2.5 cm, then the average velocity during that time interval will be

$$v_{ave} = 2.5\text{ cm} / 0.10\text{sec}$$
$$= 25\text{ cm/s}$$

Q17. How do the values of v_{ave} compare? What does this tell you about the motion of the cart?

6. Next, determine the difference in the average velocities (Δv) of the cart between two successive time intervals. Example, you can get the difference in the average velocities between strips 1 & 2, between strips 2 & 3, and so on.

Q18. How do the computed values of Δv compare? What does this tell you about the motion of the cart?

7. Recall that acceleration is defined as the change in velocity per unit of time. To get the acceleration of the cart, divide your computed values of Δv in step 6 by 0.10 seconds, the unit of time. Have at least three computed values of acceleration.

Q19. How do your computed values of acceleration compare?

8. Compute for the average acceleration a_{ave}.

9. Ask from the other groups the values of a_{ave} for the other tape charts. Record them all in Table 1 below.

Table 1. Computed values of a_{ave}

Tape chart	# of rubber bands	Computed a_{ave}
F = 1 unit	1	
F = 2 units	2	
F = 3 units	3	
F = 4 units	4	

Q20. In this activity, the number of rubber bands represents the magnitude or amount of the force acting on the cart. How is acceleration of the cart related to the amount of force acting on it?

If the net force acting on an object is constant, its velocity changes at a constant rate over time. Hence, it is considered to be moving with constant acceleration. In the tape chart, this is indicated by the uniform increase in length of the strips over time. But if the force acting on the object is changed, its acceleration will also change. In your previous activity, you noticed that as the number of rubber bands increases, the acceleration of the cart also increases. When the net force is doubled, acceleration is also doubled. When it is tripled, acceleration is also tripled. We can therefore say that at constant mass, the acceleration of an object is directly proportional to the magnitude of the unbalanced force F acting on it. This relationship can be mathematically expressed as:

$a = kF$ where k = mass

What if the mass of the object is changed and the force is kept constant? Acceleration also varies with the mass of the object. As the mass of the object increases, with the same amount of force applied, its acceleration decreases. This relationship can also be expressed as:

$a = k\,(1/m)$ where k = net force

If you combine these two relationships, you would come up with this relationship:

Law of Acceleration

"The acceleration of an object is directly proportional to the magnitude of the net force acting on it and is inversely proportional to its mass."

This statement actually pertains to Newton's second law of motion or Law of Acceleration, because it is concerned with the relation of acceleration to mass and force. This can be expressed in equation form as:

Acceleration = Net force / Mass

$$a = F_{net}/m$$

This is often rearranged as: $F_{net} = ma$

Like any other quantity, force has a unit and is expressed in Newton (N). One Newton is defined as the amount of force required to give a 1-kg mass an acceleration of 1 m/s/s, or

1Newton (N) = 1kg/ms^2

Sample mathematical problem:

Suppose a ball of mass 0.60 kg is hit with a force of 12 N. Its acceleration will be:

$$a = \frac{F_{Net}}{m}$$

$$a = \frac{12N}{0.60kg}$$

$$a = 20m/s^2$$

If the force is increased to 24 N for the same ball then,

$$a = \frac{24N}{0.6kg} = 40m/s^2 .$$

Free Fall and Newton's Second Law of Motion

Suppose you drop two books of different masses from the same height, which will hit the ground first?

Think about this: If we use the law of acceleration, the heavier book must be the one to hit the ground first because gravity pulls on it with more force. But if we use the law of inertia, the lighter book must be the one to hit the ground first because of its lesser inertia. But if you actually try it out, you would find that they will both reach the floor at the same time. How come?

Gravity acts on all objects on the earth's surface and causes them to accelerate when released. This acceleration, known as the acceleration due to gravity g, is the same for all objects on earth and is equal to 9.8 m/s^2. This means that when objects fall, their velocities increase by 9.8 m/s every 1 second.

The books in the example above fall to the ground at the same rate (acceleration) even if they differ in mass. And since they were released from the same height at the same time, they will reach the ground at the same time.

Circular Motion and Newton's Second Law of Motion

Newton's Second Law was arrived at by studying straight line motion. Does this law apply to circular motion as well?

Try to whirl an object tied to a string horizontally above your head. Then observe what happens if you release the object. How does it travel after release?

You learned in Grade 7 that acceleration does not only refer to change in speed. It also refers to change in direction. In the case of circular motion, the whirling object accelerates not due to the change in its speed but to the change in the direction of its velocity. By Newton's second law of motion, a net force must be acting on accelerating objects. So where is this net force coming from? *For the stone to move in a horizontal circle, what must you do?* You have to pull the stone inward towards the center of the circular path, right? So the force comes from the string that pulls the object towards the center of its circular path (Figure 11). If you remove this force by either cutting or releasing the string, you will observe that the object will continue to move straight and fly off tangential to the path. This is the natural tendency of the object if there is no net force acting on it, according to the First Law of Motion. But because of the net force from the string, instead of going straight, the object accelerates inwards thereby covering a circular path. The object is said to be in uniform circular motion.

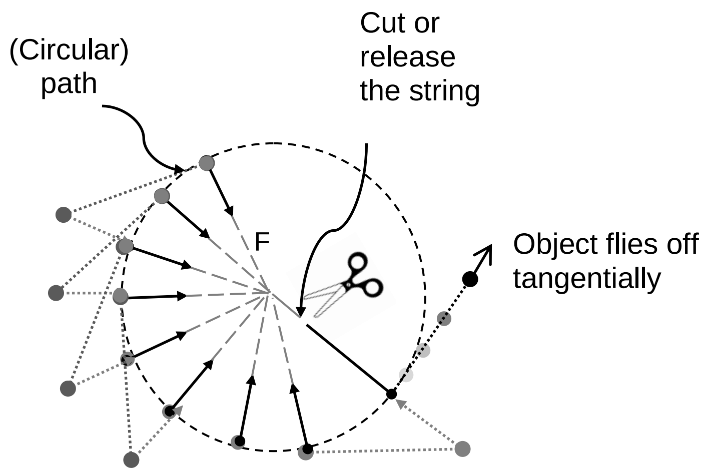


Figure 11. Object in circular motion

<u>Think about this!</u>

If the object in uniform circular motion is accelerating towards the center of the circle, why does it maintain a circular path at a constant radius and never get closer to the center of the circle?

Newton's Third Law of Motion: Law of Interaction

Activity 5
Action-reaction

Objective:

In this activity, you should be able to compare two interacting forces in terms of magnitude and direction.

Materials:

2 spring balances
string

Procedure:

1. Connect 2 spring balances with their hooks. Ask your partner to hold one end of the balance while you hold the other end horizontally. Pull the spring balance while your partner just holds the other end. Record the reading on each balance.

Q21. What is the reading on your balance and that of your partner? What do these values represent?
Q22. How do you compare the direction of your partner's and your force?

2. Pull the spring balance harder. Be careful not to exceed the maximum reading on the spring balance.

Q23. What is the reading on your balance and that of your partner?

Q24. How do you explain your observation?

3. Attach one end of your spring balance to the wall, while the other end is connected to the second spring balance. Ask your partner to pull the spring balance. Observe the reading on each balance.

Q25. What is the reading in each balance?

Q26. Compare the direction of the forces exerted on the two ends of the connected spring balance.

In the simplest sense, a force is a push or a pull. However, Newton realized that a force is not a thing in itself but part of mutual action, an interaction, between one thing and another.

For example, consider the interaction between a hammer and a nail. A hammer exerts a force on the nail and drives it into a board. But this is not the only force present for there must also be a force exerted on the hammer to stop it in the process. What exerts this force? The nail does. Newton reasoned that while the hammer exerts a force on the nail, the nail exerts a force on the hammer. So, in the interaction between the hammer and the nail, there is a pair of forces, one acting on the nail and the other acting on the hammer. Such observations led Newton to his third law: the law of interaction.

In Activity 5, you observed the similarities and differences between the interacting forces in terms of magnitude and direction. This relationship is stated in Newton's Third Law of Motion – Law of Interaction.

Law of Interaction (Action-Reaction)
"For every action, there is an equal and opposite reaction."

Because the forces are equal in magnitude and opposite in direction, do you think they will cancel each other? In this case, no addition of forces will take place because these forces are acting on different bodies. The spring balances act on each other.

The difference between the forces related to Law of Interaction and forces in a balanced state are as follows:

Action-Reaction Forces	**Balanced Forces**
• Two forces are equal in size. • Two forces are opposite to each other in terms of direction. • Two forces have the same line of action. • Action acts on one object, while reaction acts on another object.	• Two forces are equal in size. • Two forces are opposite to each other in terms of direction. • Two forces act along the same line. • Two forces act upon the same object.

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Suggested time allotment: 5 to 6 hours

Unit 1
MODULE

2

WORK AND ENERGY

Overview

In Module 1, you utilized Newton's Laws to analyze the motion of objects. You investigated the motion of an object in relation to force, mass and accel eration.

In this module, motion will be investigated from the perspective of work and energy. The concept of force, which you have taken up in Module 1, will be related to the concepts of work and energy.

At the end of this module, you should be able to answer the following questions:

What is work?
What is energy?
How are work, energy and power related?

What is *Work*?

What comes to your mind when you hear the word 'work'? The word *work* has many meanings. When people ask, "W*hat is your work?"* They refer to a job or employment. When people say, "*I'll meet you after work."* They refer to the part of a day devoted to an occupation or undertaking. When your teacher asks, "*Have you done your homework*?" They refer to the task or activity needed to be accomplished.

In Physics, *work* is an abstract idea related to energy. When work is done it is accompanied by a change in energy. When work is done by an object it loses energy and when work is done on an object it gains energy.

In Module 1, you learned that force can change the state of motion of an object. If an object is at rest, it can be moved by exerting force on it. If an object is moving, it can be made to move faster or stopped by applying force on it. In order to say that work is done on an object, there must be force applied to it and the object moves in the direction of the applied force.

Work is done if the object you push moves a distance in the direction towards which you are pushing it.

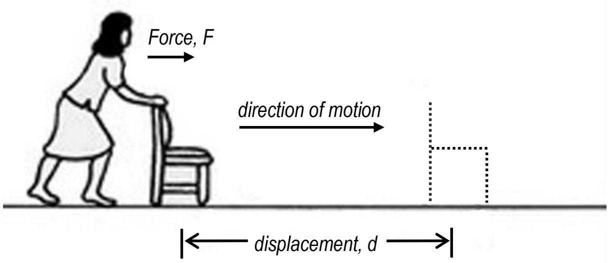


Figure 1. A girl pushing a chair

No work is done if the force you exert does not make the object move.

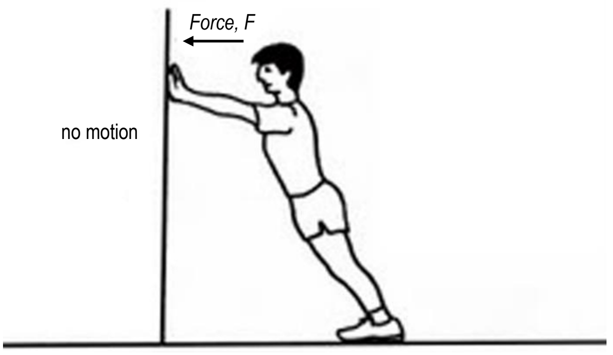


Figure 2. A boy pushing a wall

No work is done if the force you exert does not make the object move in the same direction as the force you exerted.

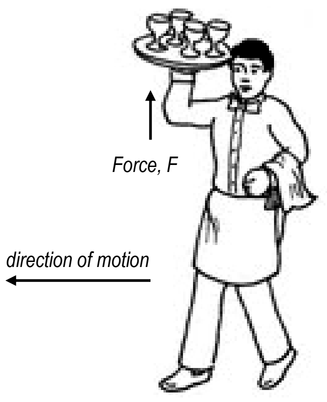


Figure 3. A waiter carrying a tray

Do activity 1 to see how well you understood ‘work’.

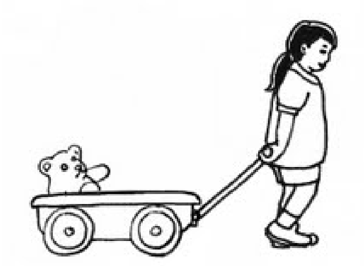
Activity 1
Is there work done?

Objective:

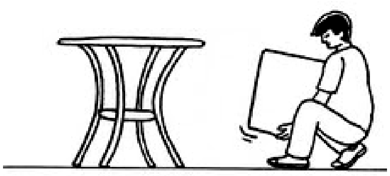
After performing this activity, you should be able to explain if work is done in situations represented.

Procedure:

Tell whether the situations shown below represent examples of work. Identify the one doing the work and on which object the work is done. Write in your notebook your answers and explanations.

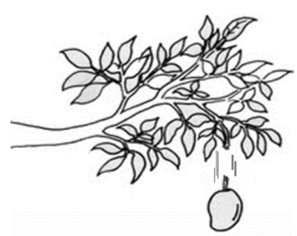


1. A girl pulling her cart.



2. A man lifting a box to be placed on a table.

3. A girl carrying a bag walking down a street.



4. A mango fruit falling from a branch.

Calculating Work

Work is done when the force (**F**) applied to the object causes the object to have a displacement (**d**) in the same direction as the force applied. The symbol for work is a capital **W**. The work done by a force can be calculated as

$$W = Fd$$

As you have learned in Chapter 1, the unit of force is

$$unit\ of\ force = kg\frac{m}{s^2} \text{ or } newton, N$$

Hence, the unit for *Work*, *W*

$$W = Fd$$

$$unit\ of\ work = unit\ of\ force\ x\ unit\ of\ displacement$$

$$unit\ of\ work = N\ m$$

$$unit\ of\ work = Nm \text{ or } joules, J$$

The unit, joule (J) is named after the English Physicist James Prescott Joule. This is also a unit of energy. One (1) Joule is equal to the work done or energy expended in applying a force of one Newton through a distance of one meter.

<u>Sample problem:</u>

Suppose a woman is pushing a grocery cart with a 500 Newton force along the 7 meters aisle, how much work is done in pushing the cart from one end of the aisle to the other?

$$W = Fd$$

$$W = 500\ N\ (7\ m)$$

$$W = 3500\ Nm$$

$$W = 3500\ J$$

Try solving this:

A book of mass 1 kg is on the floor. If the book is lifted from the floor to the top shelf which is 2 meters from the floor, how much work is done on the book?

Work is a Method of Transferring Energy

In Grade 7, you learned that there are different ways by which energy can be transferred from one place to another. Sound and light are transferred by waves; electrical energy is transferred by moving electrical charges through a complete circuit; and heat is transferred either by randomly moving particles, or by electromagnetic waves. Work is also a means of transferring energy from one object to another.

Do this!
Play a bowling game. Roll a plastic or rubber ball along the floor to hit an empty plastic bottle.

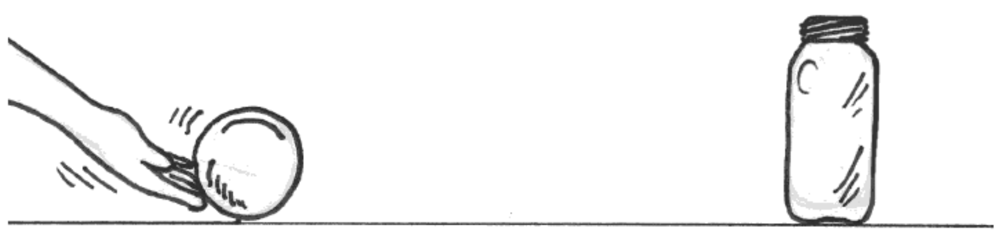


Figure 4. A ball and a plastic bottle

Is there work done on the ball?
What can a moving ball do?

You have done work on the ball. The force you exerted in pushing the ball is in the same direction as the motion of the ball. But then you did not continuously push the ball until it hits the empty bottle. You just gave it a nudge and then it rolled The force exerted on the ball changed the ball's motion. *'Something'* was transferred to the ball causing it to move continuously. That *'something'* is called energy. The energy became energy of motion of the ball.

A rolling ball can do work on the plastic bottle. When the ball hits the plastic bottle, it can push it through a distance. Thus, a moving object can do work on anything it hits because of its motion energy. Hence, energy is oftentimes defined as the ability or capacity to do work.

Since work is done on the ball, it gains energy while the person that does work on it loses energy. In the same manner, the rolling ball that does work on the empty plastic bottle loses energy while the bottle gains energy. This shows that when work is done, energy is transferred.

Kinetic Energy

The energy of a moving object is called energy of motion or kinetic energy (KE). The word kinetic comes from the Greek word *kinetikos* which means moving. Kinetic energy quantifies the amount of work the object can do because of its motion.

The plastic or rubber ball you pushed to hit an empty plastic bottle earlier has kinetic energy. The force applied caused the ball to accelerate from rest to a certain **velocity, *v*.** In Module 1, you learn that acceleration is the rate of change in velocity. In the equation,

$$a = \frac{v - v_i}{t}$$

where ***v*** is the final velocity, $\mathbf{v_i}$ is the initial velocity and **t** is the time.

Since the ball started from rest, the initial velocity is zero. Thus, the acceleration is

$$a = \frac{v}{t}$$

Substituting this in Newton's second law

$$F = ma$$

$$F = m\frac{v}{t}$$

The equation in finding the average velocity of the ball is

$$\bar{v} = \frac{v_i + v_f}{2}$$

Since the initial velocity is zero, the average velocity, $\boldsymbol{\bar{v}}$ is

$$\bar{v} = \frac{v_f}{2}$$

or

$$\bar{v} = \frac{v}{2}$$

The distance travelled by the ball before it hits the empty plastic bottle is given by the equation

$$d = \bar{v}t$$

where $\bar{v}$ refers to the average velocity

$$d = \frac{v}{2}t$$

Let's put the equations together. Since $\boldsymbol{W = Fd}$ and $\boldsymbol{F = \frac{mv}{t}}$**,** we get

$$W = \frac{mv}{t}d$$

$$W = \frac{mv}{t}(\frac{1}{2}vt)$$

$$W = \frac{1}{2}mv^2$$

This shows that the work done in accelerating an object is equal to the kinetic energy gained by the object.

$$KE = \frac{1}{2}mv^2$$

From the equation, you can see that the kinetic energy of an object depends on its mass and velocity. What will happen to the KE of an object if its mass is doubled but the velocity remains the same? How about if the velocity is doubled but the mass remains the same?

As you have learned in Module 1, the unit for *mass* is *kg* while for *velocity* it is *meter per second*.

Hence, the unit for *Kinetic Energy*, *KE* is

$$unit\ of\ KE = unit\ of\ mass\ x\ unit\ of\ velocity$$

$$unit\ of\ KE = \ kg\left(\frac{m}{s}\right)^2$$

$$unit\ of\ KE = kg\frac{m^2}{s^2}$$

But,

$$kg \cdot \frac{m}{s^2} = 1\ newton, N$$

$$unit\ of\ KE = Nm\ or\ joules, J$$

Try solving this:

A 1000 kg car has a velocity of 17 m/s. What is the car's kinetic energy?

Potential Energy

In activity 1 you were asked if the illustration of a man lifting a box demonstrates work.

Figure 5. A man lifting a box

Which/who is doing work in the illustration? Is it the table, the box, or the man? Yes you are correct if you answer “The man is doing work on the box.” What is the direction of the force exerted by the man on the box? Yes, it is upward. What is the direction of the motion of the box? Yes, it is upward. Then we can say, work is done by the man on the box.

As discussed previously, work is a way of transferring energy. Since the work is done by the man, he loses energy. The work is done on the box, hence the box gains energy.

In Grade 6, you learned about the force of gravity. It is the force that the earth exerts on all objects on its surface. It is always directed downward or towards the center of the earth. Hence, when an object is lifted from the ground, the work done is against the force of gravity. An object gains energy when raised from the ground and loses energy when made to fall. The energy gained or lost by the object is called *gravitational potential energy* or simply potential energy (PE).

For example when a 1.0 kg book is lifted 0.5 m from the table, the force exerted in lifting the book is equal to its weight.

$$F = Weight = mg$$

The acceleration due to gravity, ***g*** is equal to 9.8 meters per second squared.

The work done in lifting the book is

$$W = Fd$$

where the displacement (***d****)* is the height (***h)*** to which the object is lifted.

$$W = mgh$$

This shows that the work done in lifting an object is equal to the potential energy gained by the object.

$$PE = mgh$$

The potential energy of the book lifted at 0.5 m relative to the table is:

$$PE = 1\ kg\ x\ 9.8\ \frac{m}{s^2}\ x\ 0.5\ m$$

$$PE = 4.9\ J$$

If the book is lifted higher than 0.5 m from the table, what would happen to its potential energy?

The potential energy gained and lost by an object is dependent on the reference level. Consider a table and a chair shown in Figure 6. If the same 1.0 kg book is held 1 m above the table, the potential energy gained by it is 9.8 J with the table as the reference level; it is 14.7 J if the reference level were the chair; and 19.6 J if the reference level were the floor. If the book is released from a height of 2 m, the potential energy lost when it reaches the level of the table top is 9.8 J; 14.7 J when it reaches the level of the chair; and 19.6 J when it reaches the floor.

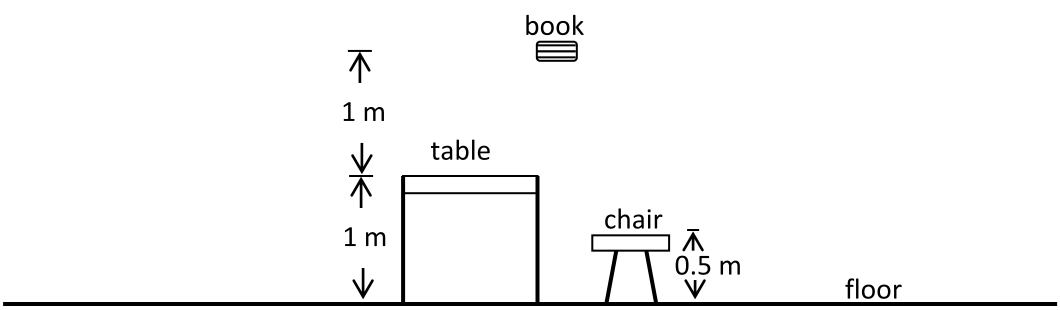


Figure 6. A table and a chair

Try solving this:

If the same 1.0 kg book is lifted to 0.5 m above the table, but the table top is 1.0 m above the floor, what would be the potential energy of the book if the reference level were the floor?

The energy of an object above the ground is called potential energy because it is a 'stored' energy. It has the potential to do work once released. Think of water held in a dam. It has potential energy. Once released, the water has the potential to move objects along its way. The potential energy of the water is transformed into kinetic energy.

The gravitational potential energy is just one type of potential energy. Another type is the elastic potential energy. Springs and rubber bands are called elastics. When elastics are stretched and then let go, they will return to their original form if they were not stretched beyond their elastic limit.

The force needed to stretch or compress elastics depends on the elasticity of the object and the change in elongation. The relationship between the force and the change in elongation (Δl) was first observed by Robert Hooke, hence, the name Hooke's Law expressed as:

$$F \propto \Delta l$$

$$F = k\Delta l$$

The proportionality holds true as long as the elastic limit of the elastics has not been reached. The proportionality or force constant *k* is a measure of the elasticity of the material.

Consider a spring. Since the force exerted in stretching a spring causes a change in length, then work is done on the spring. When work is done, energy is transferred. Thus, the stretched spring gains potential energy. The work done to stretch the spring a distance *x* (the symbol *x* is used instead of *d*) is equal to its potential energy. In equation;

$$W = PE = \frac{1}{2}kx^2$$

The elastic potential energy depends on how much the elastic object is stretched or compressed and the elasticity of the material.

What are the games you play using rubber bands? What do you do with the rubber bands in the games? Do Activity 2 to see how a rubber band 'stores' potential energy.

Activity 2
Rolling toy

Objective:

After performing this activity, you should be able to explain how a twisted rubber band can do work and relate the work done to potential energy.

Materials Needed:

1 clear plastic container with cover
1 rubber band
1 pc 3-cm round barbecue sticks
1 pc barbecue stick with sharp part cut
masking tape

Procedure:

1. Make a hole at the center of the cover and at the bottom of the plastic container.

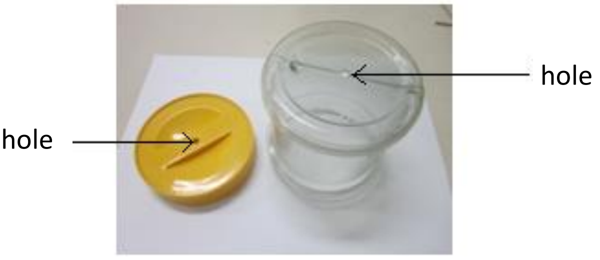


Figure 7. A plastic container with holes

2. Insert the rubber band into the hole at the bottom of the container. Insert in between the rubber band the 3-cm barbecue stick. Tape the barbecue stick to keep it in place.

Figure 8. Steps in inserting the 3-cm barbecue stick

3. Insert the other end of the rubber band into the hole in the cover. Insert a bead or a washer to the rubber band before inserting the long barbecue stick.

Figure 9. Steps in inserting the bead and the long barbecue stick

4. You just made a toy. Twist the rubber band by rotating the long barbecue stick.

Figure 10. Rotating the long barbecue stick

5. Lay the toy on the floor. Observe it.

Figure 11. Finished toy

Q1. What happens to the toy?

Q2. What kind of energy is ‘stored’ in the rubber band?

Q3. What kind of energy does a rolling toy have?

Q4. What transformation of energy happens in a rolling toy?

Work, Energy, and Power

So far, we have discussed the relationship between work and energy. Work is a way of transferring energy. Energy is the capacity to do work. When work is done by an object it loses energy and when work is done on an object it gains energy. Another concept related to work and energy is power.

Power is the rate of doing work or the rate of using energy. In equation,

$$P = \frac{Work}{time} = \frac{Energy}{time}$$

The unit for power is joules per second. But maybe, you are more familiar with *watts* which is commonly used to measure power consumption of electrical devices. The unit *watt* is named after James Watt who was a Scottish inventor and mechanical engineer known for his improvements on steam engine technology. The conversion of unit from joules per second to watts is:

$$1\ watt = \frac{1\ joule}{1\ second}$$

Do Activity 3 to see your power output in walking or running up a flight of stairs.

Activity 3
How POWER-ful am I?

Objective:

After performing this activity, you should be able to compute for your power output in walking or running up a flight of stairs.

Materials Needed:

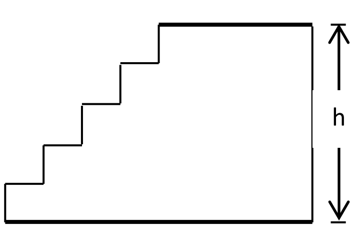
meterstick
timer

Procedure:

1. Write the group members' names in the first column of Table 1.

2. Enter each member's weight in column 2. To solve for the weight, multiply the mass (in kg) by acceleration due to gravity ($g=9.8\ m/s^2$).

3. Measure the height of the flight of stairs that you will climb. Record it on the table.



4. Each member will walk or run up the flight of stairs. Use a stopwatch or any watch to get the time it takes for each member to climb the stairs. Record the time in the 4th column.

5. Solve for the energy expended by each member. Record them in the 5th column of the table.

6. Compute for the power output of each member.

Table 1

Name	**Weight (N)**	**Height of stairs (m)**	**Time taken to climb the stairs (s)**	**Energy expended (J)**	**Power (J/s)**

Q1. Who among the group members had the highest power output?

Q2. What is the highest power output?

Q3. Who among the group members had the lowest power output?

Q4. What is the lowest power output?

Q5. What can you say about the work done by each member of the group? Did each member perform the same amount of work in climbing the stairs?

Q6. What factor/s determined the highest/lowest power output?

These are the concepts that you need to remember about work and energy:

- Work is done on an object when the force applied to it covers a distance in the direction of the applied force.
- Work is a way of transferring energy.
- When work is done by an object it loses energy and when work is done on an object it gains energy.
- The energy of an object enables it to do work.

- A moving object has energy called energy of motion or kinetic energy.
- An object above a specified level has energy due to its position called potential energy.
- An elastic object that is stretched or compressed or twisted has energy called potential energy.
- Power is the rate of doing work or the rate of using energy.

References and Links

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Suggested time allotment: 5 to 6 hours

Unit 1
MODULE
3

HEAT AND TEMPERATURE

Overview

Heat transfer happens around us all the time. Although we do not see how this process actually takes place, its effects are evident. In fact, we rely on these effects everyday in many of the activities that we do. Understanding the concepts behind heat transfer therefore helps us do our activities more efficiently.

You have learned in previous grades that heat transfer takes place between objects or places of different temperatures, and that *heat* transfers from an object of higher temperature to an object of lower temperature. You have also learned that *heat* can be transferred through conduction, convection, or radiation, and that *heat* transfers either through moving particles or electromagnetic waves. Lastly, you also learned about some factors that affect heat transfer, like the conductivity of the materials.

This time, you will learn more about heat transfer by exploring its effects on materials. You will also learn about the factors that affect the amount of *heat* that an object can absorb or release and describe how these are related to the amount of *heat* transferred.

People often interchange the use of the terms *heat* and temperature in their daily conversation. They also think that *heat* and temperature are just the same. But for physicists, *heat* and temperature are two different concepts. So in this module, you will also learn the difference between *heat* and temperature.

At the end of this module, you are expected to answer the following key questions:

What happens to solids, liquids, or gases when they absorb or release heat?

Does *heat* affect all kinds of materials in the same way?

Are heat and temperature one and the same?

Points to remember…

Remember that *heat* is the transfer of energy between objects or places because of difference in temperature. *Heat* exists as ‘energy in transit’ and it is not contained in an object. The energy that is actually contained in an object due to the motion of its particles is called thermal energy. The thermal energy of an object is changed if *heat* is transferred to or from it. Since the amount of *heat* transferred relates to the amount of change in thermal energy, the term *heat* in this module is also used to refer to the measure of thermal energy transferred.

Note also that the activities in this module involve hot and boiling water, so extra care should always be observed.

Activity 1
Explaining hotness or coldness

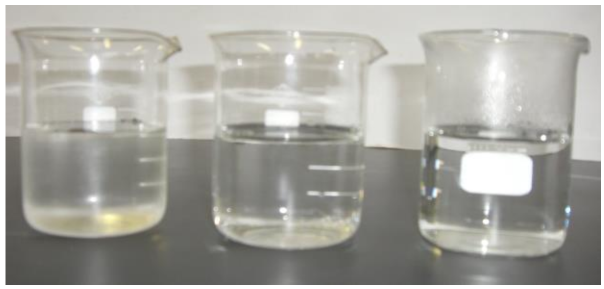
This first activity deals with one of the major effects of heat transfer, which is temperature change. You will describe the hotness or coldness of an object in terms of its temperature. You will also compare the changes in the temperature of water to determine the relationship between the amount of *heat* transferred and the resulting temperature change.

Materials Needed:

3 identical containers
thermometer
hot water
tap water (room temperature)
cold water

Procedure:

1. Half-fill the three containers with equal amount of cold water. Arrange them next to one another as shown in Figure 1 below.



1 2 3

Figure 1

2. Place your finger for a while into any of the containers.

   Try to recall your lesson on Heat Transfer in Grade 7 and answer the following questions:

Q1. What actually transferred when you dipped your finger into the water? In what direction did it transfer?

Q2. Was the water 'hot' or 'cold'? Explain.

Discuss your answers with the group. Try to estimate the temperature of the water in the containers.

3. Measure with a thermometer the temperature of the water in each container. Record your measurements in Table 1 below. (Note: The initial temperature of the water in each container should be the same as they come from the same source.)

Table 1: Data for Activity 1
Estimated temperature of water: ____ (°C)

Container	**Measured temperature (°C)**		**Change in temperature**
	Initial	**Final**	
Container 1			
Container 2			
Container 3			

Q3. How close is your estimated value to the measured temperature of the water?

4. Add the same amount of hot water to container 1, tap water to container 2 and the same cold water to container 3. Leave the containers for a while.

5. Dip your fingers again, this time into the three containers. Make sure that you do not dip the same finger into the containers.

Q4. Which container feels 'hottest'? Which container feels 'coolest'?

Q5. What do you think causes the difference in the hotness or coldness of the water inside the containers?

6. Measure and record the temperature of the water in all containers. Calculate the change in the temperature of water in each container.

Q6. In which container(s) is heat transfer taking place? What evidence best supports your answer? Within this container, which absorbs heat? Which gives off heat?

Q7. In which container was there the greatest amount of heat transferred? What is the basis of your answer?

Q8. How are the amount of *heat* transferred and the change in temperature of water related?

You have just observed that if *heat* is absorbed or given off by an object, its temperature changes. If the object absorbs *heat* its temperature rises. How do we explain the rise in temperature when heat is absorbed? In this next activity, you will take a closer look at what is actually happening at the particle level and infer what happens to the particles of an object when *heat* is added to it.

Activity 2
Dye in water

At the end of this activity, you should be able to explain the scattering of the dye in water at different temperatures.

Materials Needed:

3 transparent containers
1 thermometer
3 plastic droppers
hot water
tap water (room temperature)
cold water
dye (Food color)

Procedure:

1. Fill the three containers separately with cold water, tap water, and hot water.

2. Measure the temperature of the water in each container. Record your measurements in Table 2 below.

Table 2: Data for Activity 2

Container	**Temperature (^{0}C)**	**Observations**
Container 1		
Container 2		
Container 3		

3. With the dropper, place a drop of dye into the center of each container as shown in Figure 2. (*Note: It is better if you place drops of dye into the three samples simultaneously.*)

Figure 2

4. Carefully observe and compare the behavior of the dye in the three containers. Write down your observations in Table 2.

Q9. What similarities and differences did you observe when a drop of dye was added to each container?

Q10. In which container did the dye scatter the fastest? In which di it scatter the slowest?

Q11. How do you relate the temperature of the water to the rate of scattering of the dye?

You learned in Module 2 that moving objects possess *kinetic energy*. All the objects that you see around you that are moving possess kinetic energy. But do you know that even the very small things that you cannot see, like the particles of objects, are also moving and have kinetic energy? Take for example the water inside the containers in Activity 2. The scattering of the dye through the water indicates that the particles of water are moving. You will learn more about the movement of the particles of matter in the third quarter when you discuss about the Particle Theory of Matter.

You also noticed that the rate of scattering of the dye throughout the water differs in each container. It can then be inferred that the speed of the particles of water varies in each container. Since kinetic energy depends on speed, the kinetic energies of the particles also vary.

Q12. In which container are the particles of water moving fastest? In which container are the particles moving slowest?

Q13. How is temperature related to the speed of the particles?

Q14. How is temperature related to the kinetic energy of particles?

If *heat* is added to an object, the particles of the object gain kinetic energy and they move faster. Since temperature is directly related to kinetic energy, any gain in kinetic energy would cause the temperature to increase. Conversely, if *heat* is transferred or removed from an object, it loses kinetic energy, its particles move slower and the body's temperature decreases.

Thermal Expansion, the Working Principle of the Mercury Thermometer

You know that temperature is measured by the use of thermometer. You have most probably used this device many times. The thermometer commonly available in our schools is the liquid thermometer, which has a column of either mercury or alcohol. When the thermometer is placed in contact with any object the mercury column either rises or drops.

Now, why does the liquid inside the tube of the thermometer go up or down? This happens because the mercury inside the tube expands or contracts in response to a change in temperature. When the thermometer bulb is placed in hot water, the liquid inside the tube expands. As it does, it takes more space and so it goes up the tube. When the bulb is placed in cold water, the liquid contracts and so it goes down the tube.

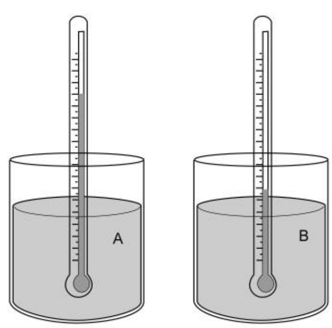


Figure 3. Thermometers in a) hot and b) cold liquid

In physics, this is called *thermal expansion*, another effect of heat transfer. But thermal expansion does not apply only to the liquid inside the thermometer. In fact, it applies to almost everything around us, be it a solid, a liquid, or a gas. If allowed by your teacher, you may try this simple activity to demonstrate expansion of a solid when heated.

Try this!

You will need: copper wire (around 2m long), candles, meterstick, 2 iron stands with clamps or rings, standard weight (or any mass around 500g)

What to do:

Prepare the setup as shown below. Make sure that the ends of the copper wire are tied or clamped firmly. Hang the *weight* in the middle of the wire. Use the candles to warm the wire at different points. Do this for 1 or 2 minutes and observe what will happen to the height of the *weight*.

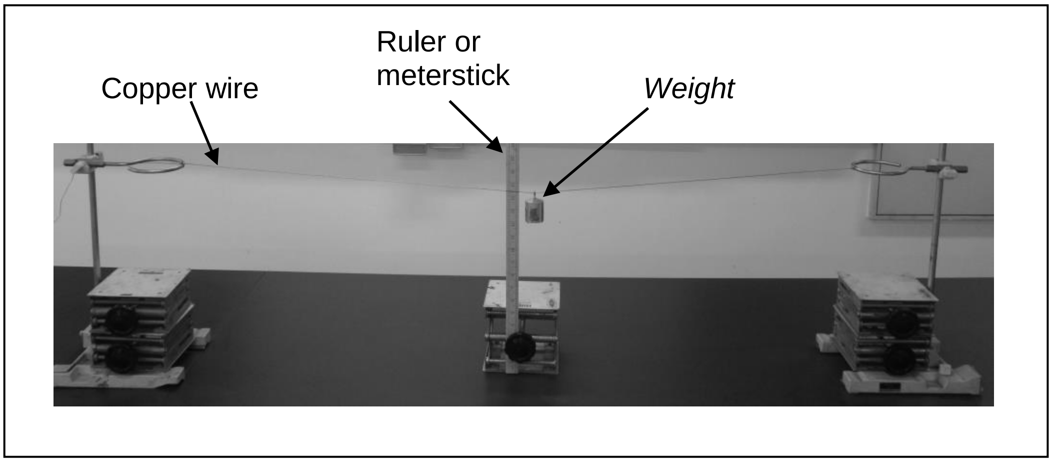


Figure 4. Setup for expansion of wire experiment

If you tried out this experiment, you would have observed that when you heated the entire length of the wire, the *weight* moved down or its height decreased a little. This indicates that the wire expanded or increased in length when heated.

There are so many applications of thermal expansion around us. Some are beneficial to us; others can also be a burden to us. One example of thermal expansion in solid is the sagging of electrical power lines or telephone wires on hot days. This happens because *heat* causes them to expand. Have you ever wondered why it is difficult to open a jar that was just taken out of the refrigerator or why motorists are advised not to overinflate their car tires or fill their gasoline tanks to the brim? How will you apply the concepts of thermal expansion to explain all these?

Phase Change

Another change that may occur when *heat* is added to or taken out from an object is phase change. For example, you know that water can change from solid (ice) to liquid (water) or from liquid to gas (steam). The next activity will allow you to observe the changes that take place when ice turns to liquid water.

Activity 3.1
What happens when ice melts?

After this activity, you should be able to answer this question:

What happens to the temperature of water while changing from ice to liquid water?

Materials needed:

crushed ice
1 glass container
timer (stopwatch)
stirring rod

Procedure:

1. Put some crushed ice and a little cold water into the container.

2. Stir the contents of the container for few seconds; then, measure the temperature of the contents.

   Avoid letting the thermometer touch the bottom of the container to ensure that you are actually measuring the temperature of the water.

Record your temperature reading in Table 3 below.

Table 3: Temperature readings for melting ice

Time (min)	Temperature (°C)
0 (Initial)	
2	
4	
6	
8	
10	
12	
14	

3. Repeat step 2 every 2 minutes. *Make sure that you stir and measure exactly the same way each time.* Record each measurement in Table 3.

Q15. Why does the ice inside the container melt after sometime?

4. Continue measuring until the ice has totally melted and even after it has already melted completely (around 4-6 minutes more).

5. Construct a temperature against time graph. Draw a smooth line that passes through almost all the points.

Q16. Which is your dependent variable? Which is your independent variable? (Note that the independent quantity is plotted along the X-axis while the dependent quantity is plotted along the Y-axis.

Q17. Describe your graph.

Q18. Describe the temperature of the water while the ice melting.

Q19. Describe the temperature of the water after the ice has melted.

Were you able to see in your graph a horizontal line similar to the part encircled in Figure 5? This was during the time when solid (ice) was turning to liquid water. During this stage, the temperature of the water remained the same, as shown by the horizontal line. Remember that a change in temperature indicates a change in kinetic energy. In this case, there was no change in the kinetic energy of the particles. So what happened to the heat energy that was continuously transferred to the water? The energy absorbed by the water is used by the particles to overcome the attractive forces between them, and not to increase the speed of particles. The temperature of the water will only start to increase after the ice has totally melted.

What if you continue to heat the water further until it boils? What do you think will happen to the temperature of the water?

Activity 3.2
What happens to the temperature of water as it boils?

Materials:

beaker
stirrer
thermometer (can measure up to 100°C)
alcohol burner
water (hot water)
stand or tripod with wire gauze

Procedure:

1. Fill the beaker with 100 mL hot water and place it above the alcohol burner using the tripod with wire gauze.

2. Measure and record the temperature of the water every 2 minutes until it boils. Once the water starts to boil, continue taking the temperature for 4-6 more minutes.

3. Plot the graph of temperature against time.

Q20. Describe and interpret your graph.

Q21. What similarities and differences have you noticed between your graphs in Activity 3.1 and Activity 3.2?

If you heat up the same sample from ice to water then from water to gas (vapor) and plot the graph of temperature vs time, it would look like the graph in Figure 5. The graph shows that the ice absorbs heat as evidenced by the temperature rise; the temperature remains the same when ice starts to melt and until all the ice has melted; then the temperature rises again until water boils. The temperature remains constant at boiling temperature when water starts turning to steam and until all the liquid water has become water vapor.

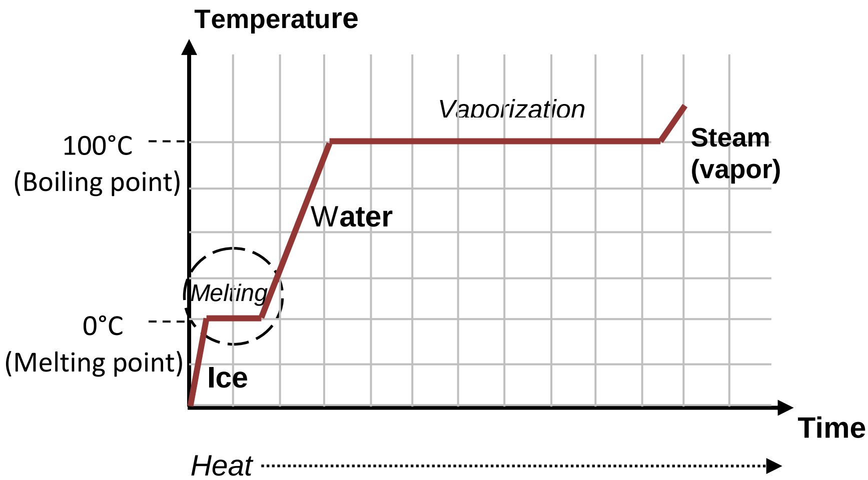


Figure 5. Phase change of water as heat is added

In Activity 1, you found that the high temperature water transferred more *heat* than water at a lower temperature. This is shown by a greater increase in temperature of the object that absorbed the *heat*. What other factors determine the amount of heat that a body can transfer?

Activity 4
What is the relationship between the mass of a material and the amount of heat it can transfer?

Task:

In this activity, your group is assigned to plan and conduct a simple investigation to determine the relationship between the mass of a material and the amount of *heat* that it can transfer. You need to gather and analyze data to come up with answers to the question given above. Apply what you learned in grade 7 about *doing simple investigations*.

1. Start with your group's prediction below:
   Prediction: ______________________________
   ____
   ____

2. Below are some guides to help you with your task.

   a. What are your variables?

      Independent variable:
      Dependent variable:
      Controlled variable (constant):

   b. What materials are you going to use for your simple investigation?

   c. What quantities are you going to measure for your data?

   d. How are you going to analyze and present your quantities (data) to describe the relationship among the variables?

3. Write your step-by-step procedure. Let your teacher check your procedure first before you proceed. Precautions should always be observed.

4. Present your data systematically.

If you were successful in your investigation, you would have realized that the amount of *heat* transferred depends not only on the temperature of the material. It also depends on the mass or amount of material. Objects with greater mass have more thermal energy and can transfer more heat.

Heat Capacity

Earlier in this module, you learned that materials expand when heated or contract when cooled. This time, you will study another thermal property of materials—their ability to absorb or release *heat* that results in temperature change. In science, the amount of *heat* needed by a material to increase its temperature by a degree is called *heat capacity (C)*. To be more specific, the term *specific heat capacity* (*c*) is used, and this refers to the amount of *heat* required to increase the temperature of one unit mass of a given material by one Celsius degree. For example, water has a specific heat capacity of 1 cal/g°C. So it takes 1 calorie of heat to raise the temperature of 1 gram of water by 1°C.

Activity 5
Comparing heat capacities

Objectives:

After performing this activity, you should be able to compare the heat capacities of the given liquid samples.

Materials:

2 identical small containers (each with 100mL of liquid sample)
2 identical large containers (large enough to accommodate the small containers)
2 thermometers
hot water
liquid samples: water, cooking oil

Note: Store the liquid samples in the same room to ensure that both are at room temperature when you do the activity.

Procedure:

1. Pour 100mL of water into one of the small containers and the same amount of cooking oil into the other container. Measure and record their initial temperature in Table 4 below.

Table 4

	Initial temperature (°C)	**Heating time (sec)**
Cooking Oil		
Water		

2. Place the small container with oil in a larger container with hot water. Make sure that the hot water does not mix with the liquid sample.

3. Measure the time it takes for the oil to increase in temperature by 5 °C. *Example, if the initial temperature of the liquid is 28°C, take the time it takes for the temperature to reach 33°C.* Record your measured heating time in Table 4.

4. Do the same with the water sample. Make sure that the amount and temperature of the hot water is the same for both samples. Record also your measurement in Table 4.

Q22. Which liquid requires more time to increase in temperature by 5 degrees?

Q23. Which liquid requires more *heat* to increase in temperature by 5 degrees?

Q24. Which liquid has a greater heat capacity?

Different materials have different specific heat capacities. Many metals have low specific heat capacities. This makes them easy to heat up and cool down. Water, on the other hand, has a high specific heat capacity and so it takes a long time to heat and a long time to cool. This makes the water a good coolant for car radiators. Because of its high specific heat capacity, it can absorb a large amount of heat without causing its temperature to rise too high.

Heat and Temperature

So far, you have already recognized the relationship between *heat* and temperature. So how do they differ? Go back to your previous experiments and analyze your findings. Then try to answer questions below.

- Which has a higher temperature, 1 cup of boiling water or 1 teapot of boiling water? Which can transfer more *heat*, 1 cup of boiling water or 1 teapot of boiling water? Explain your answer.

- Which can transfer more *heat,* a cup of boiling water or a cup of tap water? If you increase the amount of the boiling water and tap water twice, will their temperature change? Explain your answer.

- Which can transfer more *heat,* a cup of boiling water or 1 basin of tap water? (You may try this out if you have time.)

So how are *heat* and temperature different? Well, here are the important points to consider about the difference between *heat* and temperature. First, *heat* is a form of energy while temperature is not a form of energy. Temperature is a measure of the average kinetic energy of the particles and it does not depend on the mass of the object. It can be measured directly with the use of thermometers. *Heat* cannot be measured directly. But you can make use of the measurable quantities related to *heat* to determine how much *heat* (Q) is absorbed by the object. These are the change in temperature (ΔT), mass (m), and specific heat capacity (*c*) of the object. The relation among these quantities is expressed as: $Q = mc\Delta T$.

Links

Chalfant, H., Peyron, M., Rachke, C. (2005, Fall). *Heat and temperature*. *Sci Ed*, 491. Retrieved from http://www.biol.wwu.edu/donovan/SciEd491/HeatTempUnit.pdf

Expansion and contraction. (n.d.). Retrieved from http://schools.cbe.ab.ca/b682/pdfs/Science%207/Heat-and-Temperature-Unit3_T4_T6.pdf

Suggested time allotment: 6 to 8 hours

Unit 1
MODULE
4

ELECTRICITY

Overview

Electricity is a part of our daily lives. Many of the activities we do everyday depend on electricity. The discovery of electricity changed people's lives. Can you watch your favorite show on TV without electricity? Can you use your computers without electricity? Imagine our life today without electricity.

You have been learning a lot about electricity from Grade 3 to Grade 7. You have learned about its sources and uses; what materials make good conductors of electricity; what makes up an electric circuit; and how electrical energy is transferred or transformed into other forms of energy.

In this module, you will learn more about electricity. There are three quantities that you should be familiar with in the study of electricity. These are electric current, voltage, and resistance. You will use the relationships among these quantities in learning about circuit connections. You will also learn that some of the safety precautions you have been warned about can be explained by the relationships among voltage, current, and resistance.

At the end of this module you should be able to answer the following questions:

How do voltage and resistance affect electric current?

What are the safety precautions needed in using electricity?

Electric Current

In Grade 7, you learned that a circuit is any arrangement of a source of energy (battery), connecting wires, and a load (e.g. bulbs). You also learned that a complete or a closed circuit provides a path for electrical charges to flow. Electric current is a measure of the number of electrical charges passing through a cross-section of a conductor in a given time. The direction of conventional *current* or simply *current* is from the positive terminal of the battery to the negative terminal.

The symbol for current is capital letter I. The unit, ampere (A), is named after Andre-Marie Ampere, a French physicist who made important contributions to the theory of electricity and magnetism.

An ammeter measures electric current. Figure 1 shows how the ammeter is connected in a circuit. The positive terminal of an ammeter is connected to the positive terminal of the energy source (e.g. battery) while the negative terminal is connected to the negative terminal of the energy source as shown in Figure 1.

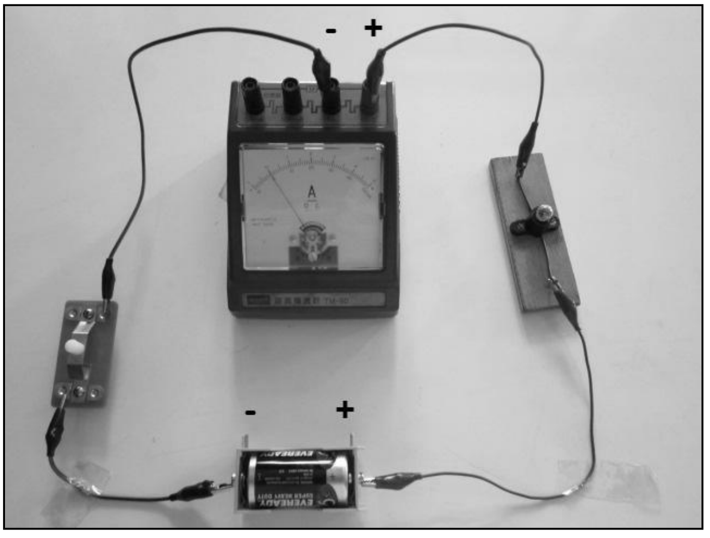


Figure 1. Ammeter connected in a circuit

Voltage

What makes the charges move in a closed circuit? In Module 2, you learned that when work is done on an object, energy is transferred which can become energy of motion of the object. In a circuit, work must be done on the charges to make them move. The battery supplies the energy in electric circuits. The chemical energy in the battery is transformed to electrical energy. This electrical energy moves the charges in a circuit.

A battery consists of several dry cells or wet cells. Both dry and wet cells contain a conducting medium called electrolyte. The batteries we use in flashlights and watches are dry cells.

The symbol for voltage is capital letter V. The unit, volts (V), is named after the Italian physicist Alessandro Volta who invented the voltaic pile, the forerunner of what we now call the dry cell.

A voltmeter measures voltage. Figure 2 shows how the voltmeter is connected in a circuit. The voltmeter should be connected across the load being tested. The positive terminal of a voltmeter is connected to the positive terminal of the bulb while the negative terminal is connected to the negative terminal of the bulb as shown in Figure 2.

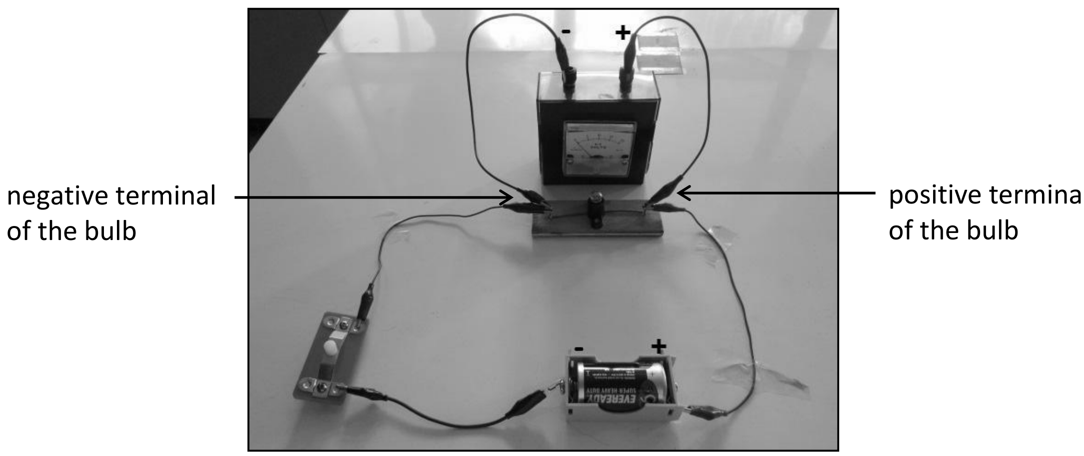


Figure 2. Voltmeter connected across the load

If voltage is needed for charges to flow, how does the amount of voltage affect current? Find out in Activity 1.

Activity 1
Current and voltage

Objectives:

After performing this activity, you should be able to:

1. measure the electric current and voltage in a circuit using an ammeter and voltmeter respectively; and

2. determine the relationship between electric current and voltage.

Materials Needed:

1 ammeter	1 voltmeter
2 dry cells (1.5 V each)	2 dry cell holders
4 connecting wires	1 switch
1 bulb	1 bulb holder

Procedure:

1. Construct a simple circuit using a dry cell, a bulb, a switch and an ammeter. Close the circuit by turning on the switch. Observe the bulb and the ammeter. Record the ammeter reading in Table 1. Upon completion of the task, switch off the circuit.

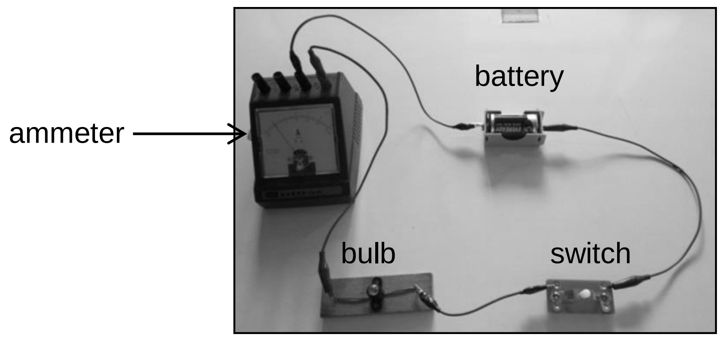


Figure 3. Ammeter connected in a circuit with one dry cell

Q1. What is the reading on the ammeter?

2. Add another dry cell to the circuit. Record the electric current measurement in Table 1. Once the task is done, turn off the switch.

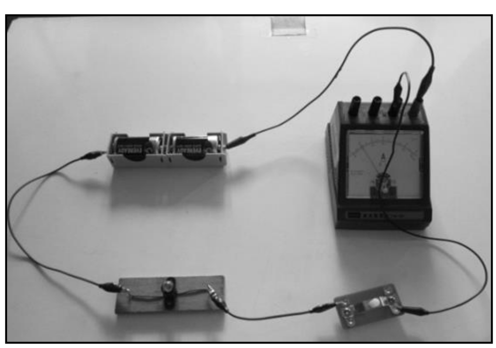


Figure 4. Ammeter connected in a circuit with two dry cells

Table 1

No. of batteries	Voltage (V)	Current (A)
1		
2		

Q2. Compare the brightness of the bulb with one dry cell to its brightness when there are two dry cells in the circuit.

Q3. What is the ammeter reading this time?

Q4. What can be inferred about the current passing through the bulb?

3. Connect the voltmeter in the circuit as shown in Figure 5. Switch on and record the voltage in Table 1. Once the task is done, turn off the switch.

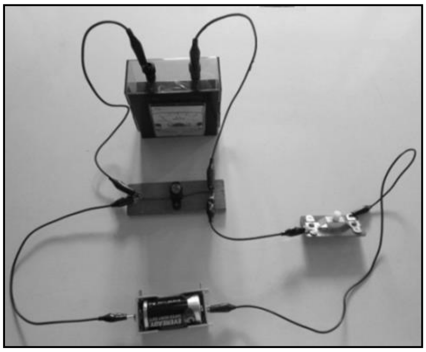


Figure 5. Voltmeter connected in a circuit with one dry cell

Q5. What is the voltmeter reading?

4. Add another dry cell to the circuit. Record the voltmeter reading in Table 1. Observe the brightness of the bulb. Once the task is done, turn off the switch.

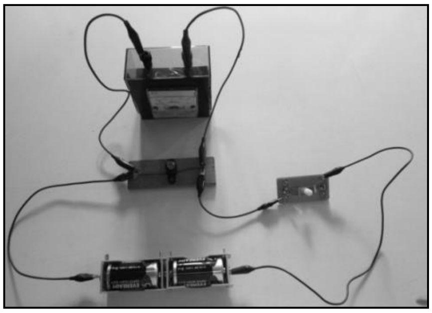


Figure 6. Voltmeter connected in a circuit with two dry cells

Q6. Describe the brightness of the bulb.

Q7. What is the voltmeter reading this time?

Q8. What can be inferred about the voltage across the bulb?

Q9. Refer to Table 1, how are voltage and current related?

In Activity 1, the current and voltage in circuits with 1 dry cell and 2 dry cells were compared. You observed that the ammeter and voltmeter readings are greater in the circuit with 2 dry cells as compared to the circuit which has only one dry cell. Also, the bulb in the circuit with 2 dry cells glowed brighter than the bulb in the circuit with only 1 dry cell. The activity showed that as the voltage increases, the current also increases.

However, a circuit is not only about voltage and current. There is another component which is the load. A load is any component in a circuit that converts electricity into light, heat, or mechanical motion. In the circuit you constructed in Activity 1, the bulb is the load. If two bulbs were used in the circuit, would there be a change in the circuit current? You will find out in Activity 2.

Resistance

When electric charges flow through the wires and loads of the circuits they encounter resistance or a hindrance to their movement. So another factor that affects the flow of charges or current is resistance.

The symbol for resistance is capital letter R. The unit, ohms (Ω) is named after the German physicist Georg Simon Ohm.

How is current affected by the resistance of the load in a circuit? Do activity 2 to find out.

Activity 2
Current and resistance

Objectives:

After performing this activity, you should be able to determine the relationship between electric current and resistance.

Materials Needed:

1 ammeter	2 dry cells
2 dry cell holders	4 connecting wires
1 switch	3 flashlight bulbs (voltage rating of 2.5V each)
3 bulb holders	

Procedure:

1. Construct a simple circuit using one bulb, 2 dry cells and an ammeter as shown in Figure 7. Record the electric current measurement in Table 2. Once the task is done, turn off the switch.

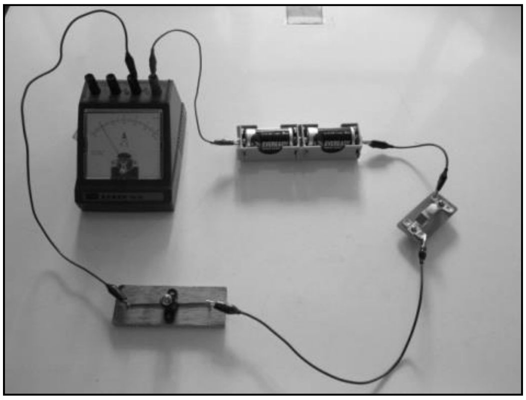


Figure 7. Ammeter connected in a circuit with one bulb and two dry cells

2. To increase the resistance, add another bulb in the circuit. Connect the ammeter and record the electric current measurement in Table 2. Once the task is done, turn off the switch.

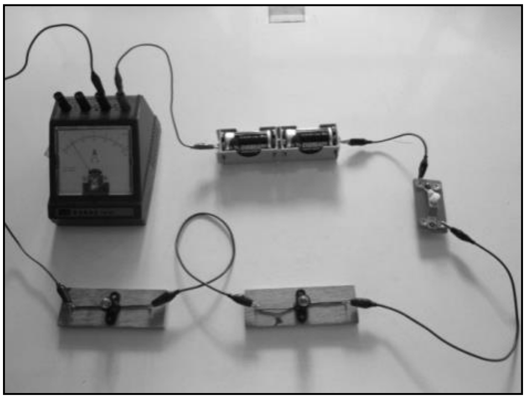


Figure 8. Ammeter connected in a circuit with two bulbs and two dry cells

3. To further increase the resistance, add another bulb in the circuit. Connect the ammeter and record the electric current measurement in Table 2. Once the task is done, turn off the switch.

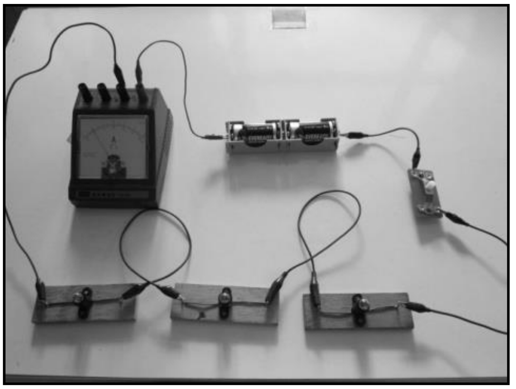


Figure 9. An ammeter connected in a circuit with three bulbs and two dry cells

Table 2

No. of bulbs	Current (A)
1	
2	
3	

Q10. Based on Table 2, what happens to the current in the circuit as the resistance increases (increasing of bulbs)?

4. Connect the ammeter at different points around the circuit shown in Figure 10. Make sure that the positive terminal of the ammeter is connected to the positive terminal of the dry cell while the negative terminal is connected to the negative terminal of the dry cell. Once the task is done, turn off the switch.

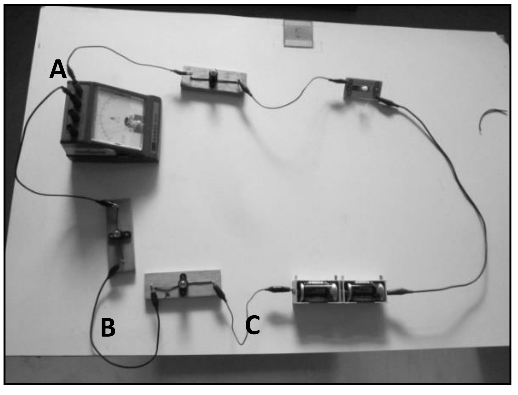


Figure 10. Ammeter connected between two bulbs in a circuit

Q11. Compare the current at different points in the circuit.

Q12. What can you infer about the current through the circuit?

In Activity 2, you added bulbs to the circuit to see if the current in the circuit will be affected. You observed that keeping the number of dry cells the same, adding more bulbs resulted in a decrease in current. Since adding more bulbs means increasing the resistance in the circuit, it can be inferred that the resistance limits the current in the circuit. You further observed that the current is the same in any part of the circuit as evidenced by the ammeter readings.

How is the result in Activity 1, related to the result in Activity 2? The results of Activity 1 showed that for a fixed resistance (one bulb), as the voltage increases, the current also increases. For Activity 2, the results showed that keeping the voltage the same (2 dry cells), when the resistance increases, the current decreases.

At this point, you are already very familiar in constructing a circuit. In Activity 3 you will find out if connecting loads in different ways would affect the current and voltage of the circuit

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Activity 3
What's the connection?

Objectives:

After performing this activity, you should be able to:

1. connect loads in different ways and
2. explain the similarities and differences between the circuit connections.

Materials Needed:

For Circuit A:
3 connecting wires
2 identical bulbs with holder
2 dry cells with holder

For Circuit B:
4 connecting wires
2 identical bulbs with holder
2 dry cells with holder

voltmeter for both circuits

Procedure:

1. Construct a circuit using three connecting wires, two identical bulbs and two batteries such that when one bulb is unscrewed the other bulb goes out also. Once you're done with the task, disconnect the battery from the circuit.

2. Draw your setup. Label this Circuit A.

3. Trace the paths of current in Circuit A.

Q13. How many path/s of current are there in the circuit?

Q14. Why did the other bulb go out also when you unscrewed the other?

4. This time, construct a circuit using four connecting wires, two identical bulbs and two batteries such that when one bulb is unscrewed, the other bulb remains lighted. Once you're done with the task, disconnect the battery from the circuit.

5. Draw your setup. Label this Circuit B.

6. Trace the path of current in Circuit B.

Q15. How many paths can the current take in Circuit B?

Q16. Explain why the other bulb remains lighted when you unscrewed one of them.

7. Put Circuits A and B side by side. Observe the brightness of the bulbs.

Q17. Which circuit has brighter bulbs, A or B?

Q18. Based on the brightness of the bulbs, compare the current in Circuit A and in Circuit B?

8. Measure the voltage across the two bulbs as well as the voltage across each bulb in Circuit A. Record your readings in Table 3. Do the same in Circuit B.

Table 3

Circuit	**Voltage drop (V)**		**Voltage across the two bulbs (V)**
	Bulb 1	**Bulb 2**	
A			
B			

In Circuit A, the bulbs are connected in series, while in Circuit B, the bulbs are connected in parallel. Series and parallel connections are the two ways of wiring loads. In a series connection, there is only one path for the current. In a parallel connection the current from the battery can branch out to the two bulbs. Hence the current can take the path through Bulb 1 and the path through Bulb 2.

The current in Circuit A takes only one path, passing through the two bulbs. When one bulb is unscrewed or removed, a gap is created. A gap or a break anywhere in the path stops the flow of charges and therefore no current passes through to the other bulb.

In Circuit B, the current can take two paths - one path for each bulb. When one bulb is unscrewed or removed, the other bulb is still part of a complete circuit and remains lighted.

Let us compare the other characteristics of Circuits A and B. Circuit A is similar to the circuit of three bulbs you made in Activity 2. The bulbs are connected in series. In this type of connection, the resistance increases with the number of bulbs added in the circuit. The total resistance in the circuit is the sum of the resistance offered by each bulb.

You observed in Activity 2 that as the total resistance increases, the current through the circuit decreases. You also measured the current and voltage at different parts of the circuit. Your measurements showed that the current is the same anywhere in a series circuit, and the sum of the voltages across each bulb equaled that of the voltage source.

On the other hand, Circuit B has 2 bulbs which are connected in parallel. You observed that the voltage across each bulb is almost equal to the voltage of the two dry cells, indicating that the voltage anywhere in the circuit is the same. However, when the brightness of the bulbs in Circuit B is compared to that of the bulbs in Circuit A, those of Circuit B were brighter than those of A. This means the current in B is greater than the current in A. Since the voltage in A and B are the same (2 dry cells), the greater current in B indicates that the total resistance of Circuit B is less than the total resistance of Circuit A. We can infer that when loads (bulbs) are connected in parallel, the total resistance of the circuit decreases; when the loads are connected in series, the total resistance increases. Table 4 compares the total current, total voltage and total resistance of series and parallel circuits.

Table 4

	Series connection	**Parallel connection**
Total current	Same as current in individual load	Equal to the sum of current in individual loads
Total voltage	Equal to the sum of the voltages across each load	Same anywhere across two points in the circuit
Total resistance	Increases with increasing load	Decreases with increasing load

Look at the connections of wirings in your house. Which are connected in series? Which are connected in parallel? What are the advantages and disadvantages of each type of connection?

Safety in Using Electricity

Your parents have probably cautioned you about the use of electrical devices even before you reached school age. You were told not to touch electrical outlets or insert anything into it. You were told not to touch any electrical wires in the house. Well they may not have explained it to you back then, but they have valid reasons.

Firemen advise homeowners to check the electrical connections in their homes especially the condition of the wires. They advise homeowners to replace exposed electrical wires. Why is there a need to cover exposed wires? You will find the answer in Activity 4.

Activity 4
Stay safe!

Objectives:

After performing this activity, you should be able to:

1. describe the heating effect of current;
2. explain what a short circuit is; and
3. explain the reason behind some safety practices in the use of electricity.

Materials Needed:

For Activity 4A
2 dry cells in a battery holder
2 connecting wires
1 fine strand of copper wire (20 cm long)
2 small blocks of wood
4 thumbtacks
2 short candles
Timer

For Activity 4B
2 connecting wires
2 dry cells in a battery holder
1 bulb in a bulb holder

Procedure:

4A. What makes it hot?

1. Place two wooden blocks side by side. To keep them from being moved, place masking tape underneath each block to keep them steady on the table.

2. Place two thumbtacks on each wooden block near the space between them. Wrap the copper wire tightly around the thumbtacks as shown, leaving two free

ends on the same wooden block. Press the thumbtacks fully until the head of the thumbtacks is just above the wood.

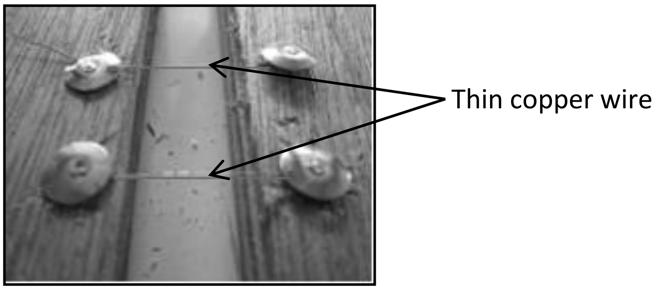


Figure 11. Copper wire wrapped around the thumbtacks

3. Place a candle on top of the wires as shown below.

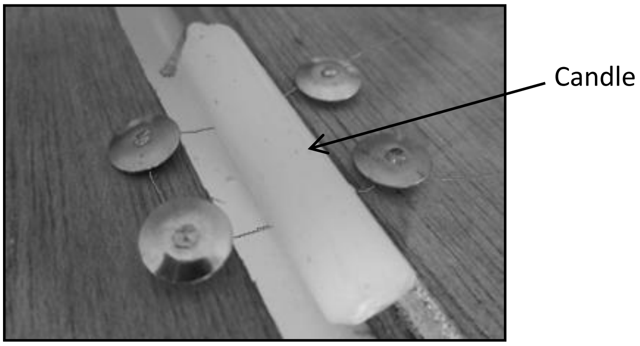


Figure 12. A candle on top of the copper wires

4. Connect the two free ends of the copper wire to the battery using the connecting wires. Leave the circuit closed for 30 seconds and then disconnect the battery. Observe the candle. Write your observation and explanation.

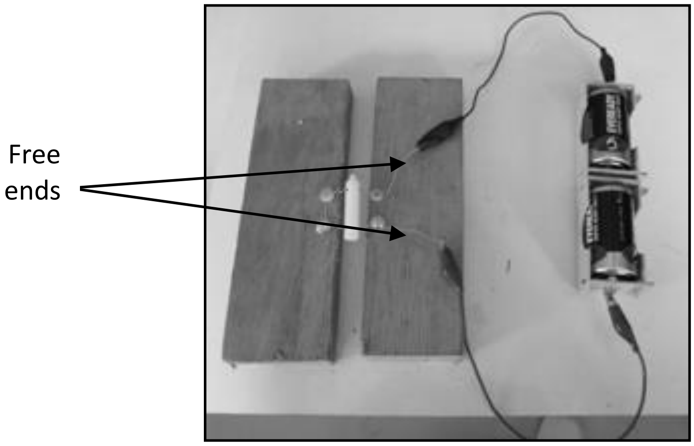


Figure 13. A circuit with copper wires connected to two dry cells

5. Try adding another dry cell as shown in the circuit using another candle. Repeat steps 3 and 4 and write your observation.

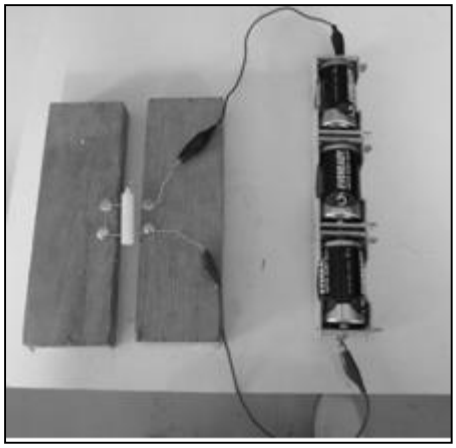


Figure 14. A circuit with copper wires connected to three dry cells

Q19. What happened to the candle for both setups?

Q20. When you increase the voltage by adding another dry cell, what happens to the amount of current in the circuit?

Q21. Compare the effect on the candle with two dry cells and with three dry cells in the circuit. What is produced in the wires that affected the candle? How does the effect on the candle relate to the amount of current in the wire?

4B. Don't keep it short!

1. Remove about 2 cm insulation from the ends of the connecting wires.

2. Construct a circuit using the bulb, 2 batteries, and connecting wires with exposed parts you made in step 1.

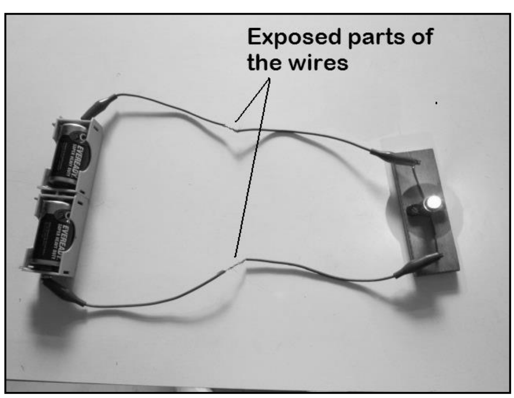


Figure 15. A circuit with exposed wires

3. Make the exposed parts of the wire touch momentarily. Do not keep them in contact for so long.

Q22. What happened to the bulb?

4. Draw the setup and trace the path the current takes when the exposed parts of the wires touch each other.

Q23. Explain what happened to the bulb when the exposed wires momentarily touched.

Q24. When the exposed wires were momentarily touched the path of current was shortened (hence the term short circuit) compared to the original path which include the bulb. What was the effect on the resistance of the circuit when the path of current was shortened or when a short circuit occurred?

Q25. What was the effect on the current when a short circuit occurred?

Q26. Why do short circuits cause fire?

A short circuit happens when the exposed parts of the electrical wires touch one another. When the exposed wires were made to touch, a shortened path was provided for the current, hence the term short circuit. Since the path has been shortened, current will no longer take the path through the bulb, thereby decreasing the total resistance in the path of current. This will result in a large current in the shortened circuit. Short circuits are dangerous especially with the high line voltage in our houses (220V compare to 1.5V of dry cells) because the large current produced can generate a lot of heat that could start a fire.

The current that a wire of given diameter can safely carry is indicated by its current rating. When the current in the circuit exceeds the wire's current rating, **an overload of the circuit** occurs. Overloading can also generate a lot of heat in the wire that can cause a fire outbreak.

In designing electrical installations, engineers estimate the current requirements of appliances and electrical devices the owner intends to use and make these as the basis for selecting the appropriate size of wire in wiring the house.

When there are too many appliances plugged into one outlet (also called octopus wiring) the loads are effectively connected in parallel and overloading may also occur. Figure 16 shows an example of octopus wiring.

Q27. What happens to the total resistance of the circuit when more and more appliances are connected to one outlet?

Q28. What happens to the total current?

Q29. Overloading a circuit can start a fire. Explain.

Figure 16. Octopus wiring

Summary

Electric charges can only flow continuously in a complete circuit. The voltage provides the energy that moves the charges in the circuit. The current is determined by the voltage and the total resistance of the circuit. Current is directly proportional to voltage but inversely proportional to resistance.

In a series circuit, the loads are connected to form a single pathway for electric charges to pass. In a parallel circuit, the loads are connected to form branches, each of which provides a separate path for current.

A short circuit happens when the circuit offers little or no resistance to the flow of charges. This results in a large amount of current in the circuit. When the current in the circuit exceeds the wire's current rating, overload of the circuit occurs.

Link

All About Circuits. (2003-2012). *Ohm's law (again!)*. Retrieved from http://www.allaboutcircuits.com/vol_1/chpt_3/4.html

Suggested time allotment: 6 to 8 hours

Unit 1
MODULE
5

SOUNDS

Overview

“*Hey I just met you and this is crazy. So here’s my number so call me maybe...*” This is the popular song of Carly Rae Jepsen. I bet you know this song. Can you sing the other lines? Is this the ring tone of your mobile? What about your ring back tone? Would you want that of Maroon 5’s payphone? “*Cadd9 I’m at the payphone trying to G call home. Em All of my change I’ve spent Dsus4 on you...”* These are cool, lovely tunes, and nice sounds.

The Science of Sound has gone all the way from a mere transfer of energy to the creation of tunes and music for entertainment. Most of our gadgets are sound embedded to amuse us. In the field of geology and oceanography, sound is used to determine depths. The health sciences are also using sound for medical purposes. Some animals are dependent on sound for movement. The newest focus of sound science is on ecology where ecological patterns and phenomena are predicted based on sounds released by the different components of the ecosystem. So, are you ready to have fun with sounds?

In this module, you will learn sound propagation. While you learn about sound, wave description and characteristics will also be introduced to you. Among the characteristics, you will focus on the speed of sound. You will find out through simple activities through which medium sound travels fastest. You will also find out how the temperature of the medium affects the speed of sound. In the quest to explore more about sound science, you will be acquainted with the properties of waves, specifically reflection and refraction.

Through which medium does sound travel fastest- solid, liquid, or gas?
How does the temperature of the medium affect the speed of sound?
How are reflection and refraction manifested in sound?

Propagation and Characteristics of Sound

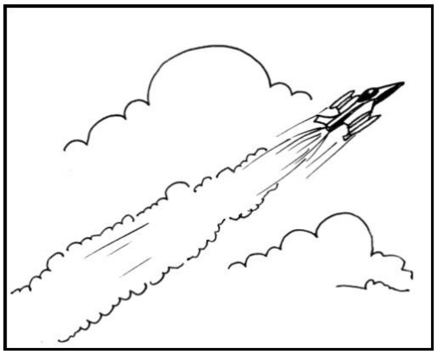


Figure 1. Supersonic

Figure 2. Hearing Sounds

Have you experienced hearing a sonic boom? Figure 1 shows a whitish cloud at the tail end of the aircraft. This usually happens when the aircraft travels at a speed faster than the speed of sound, i.e., the aircraft travels at supersonic speed producing a sonic boom.

A sonic boom happens when the aircraft or any vehicle breaks the sound barrier while it accelerates and outruns the speed of sound. A loud explosive sound is heard on the ground and is called a sonic boom. The aircraft that does this is usually called supersonic. There are more amazing occurrences or phenomena related to sound. Read on and find out.

- **Sound Propagation**

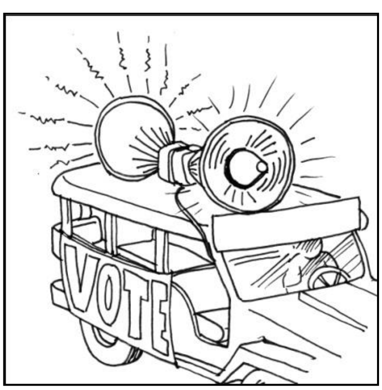


Figure 3. Propagating Sound

Sound consists of waves of air particles. Generally, sound propagates and travels through air. It can also be propagated through other media. Since it needs a medium to propagate, it is considered a mechanical wave. In propagating sound, the waves are characterized as longitudinal waves. These are waves that travel parallel to the motion of the particles. Do all these terms and concepts seem confusing? Let's try the succeeding activities to get a clearer picture of what sound waves are.

Activity 1
The dancing salt and the moving beads!

Objectives:

At the end of the activity, you will be able to infer that:

1. sound consists of vibrations that travel through the air; and

2. sound is transmitted in air through vibrations of air particles

Materials:

1 rubber band
1 piece of plastic sheet
1 empty large can of powdered milk - 800 g
1 wooden ruler
1 empty small can of evaporated milk - 400 mL
rock salt
1 dowel or 1 wooden rod
1 blue bead
4 colored beads
3 inches of tape
2 large books
scissors
5 pieces of string
paper
slinky spring
transistor radio

Procedure:

Part A: Vibrations produce sound

1. Prepare all the materials needed for the activity. Make sure that you find a work area far enough from other groups.

2. Put the plastic tightly over the open end of the large can and hold it while your partner puts the rubber band over it.

3. Sprinkle some rock salt on top of the plastic.

4. Hold the small can close to the salt and tap the side of the small can with the ruler as shown in Figure 4.

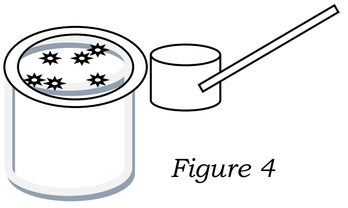


Figure 4

Q1. What happens to the salt?

5. Try tapping the small can in different spots or holding it in different directions. Find out how you should hold and tap the can to get the salt to move and dance the most.

Q2. How were you able to make the salt move and dance the most?

Q3. What was produced when you tapped the small can? Did you observe the salt bounce or dance on top of the plastic while you tapped the small can?

Q4. What made the salt bounce up and down?

Q5. From your observations, how would you define sound?

6. Switch on the transistor radio and position the speaker near the large can. Observe the rock salt.

7. Increase the volume of the radio while it is still positioned near the large can. Observe the rock salt again.

Q6. What happened to the rock salt as the loudness is increased?

Q7. Which wave characteristic is affected by the loudness or the intensity of sound?

Part B: Transmitting sound

8. Let 2 books stand up as shown in Figure 5. Place the dowel on top of the 2 books.

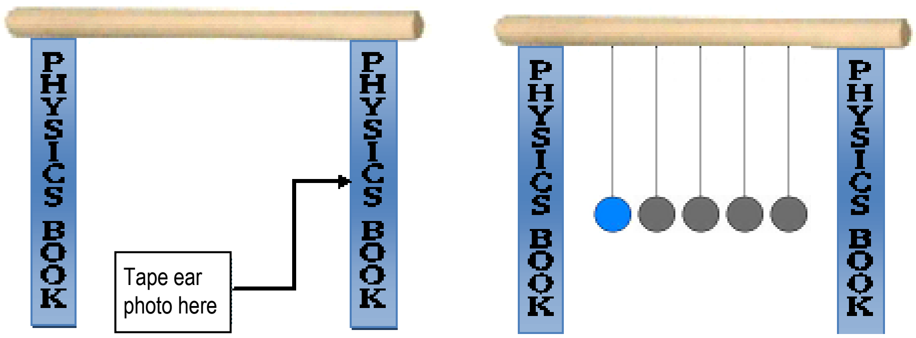


Figure 5. Set up for Activity 1B

9. Cut out an image of a human ear from a magazine and tape it to one of the books.

10. Start with the blue bead. Tape the string to the mark on the dowel that is farthest away from the ear.

11. Then tape the 4 colored beads to the other 4 marks. Make sure that all the beads hang in a straight line.

12. The colored beads represent air particles. Create vibrations (sound) in the air by tapping the blue bead toward the colored beads.

Q8. What happens to the other colored beads when the blue bead is tapped?

13. Create more vibrations by continuously tapping the blue bead and observe the other beads.

Q9. Are there occasion when the beads converge then expand?

14. If the beads represent air particles, what do the converging and expanding of the beads represent?

15. Connect one end of the slinky to a fixed point. Hold the other end then push and pull the slinky continuously. Record your observations.

Q10. Are there converging and expanding parts of the slinky?

Q11. How then is sound classified as a wave?

16. This time shake the other end of the slinky while the other end is still connected to the fixed point. Record your observations.

Were you able to get good sets of data from the activity? Did you enjoy watching the salt dance and the beads move? The salt and the beads represent particles of air when disturbed. The disturbance encountered by the salt and the beads causes the salt to bounce up and down and the beads to move together and spread alternately. In grade 7, you discussed that energy is transferred or transmitted from one object to another. Bouncing salt is also a manifestation of energy transmission. When sound is created by tapping the small can, the wave (sound) is transmitted by air to the larger can causing the plastic cover of the larger can to vibrate transferring energy to the rock salt. And voila!—dancing rock salt!

What about the beads? Did you observe the alternating converging and spreading of the beads? Compare this to your observations in the slinky spring. The converging portions of the beads match the compressions in the slinky while the spreading portions are the rarefactions of the slinky. With the compressions and rarefactions, what you were able to produce is called a longitudinal wave. Longitudinal waves are waves that are usually created by pulling and pushing the material or medium just like in the slinky (Figure 6). Alternating compressions and rarefactions are observed. These compressions and rarefactions move along with the direction of the pushing and pulling activity of the material or medium. Thus, the wave moves parallel to the motion of material or the particles of the medium. This is known as a **longitudinal wave**.

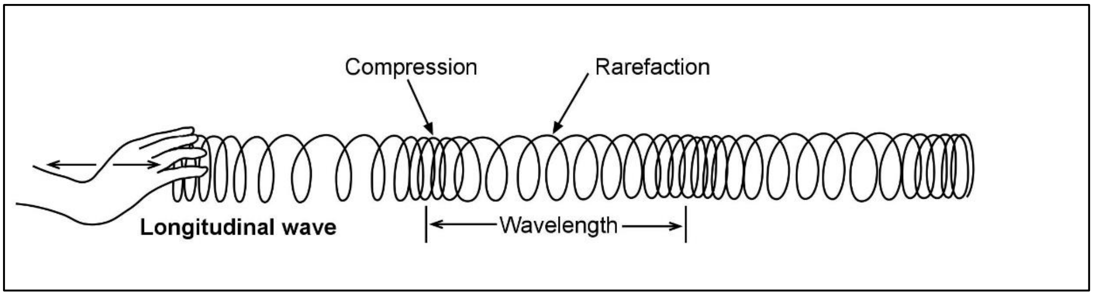


Figure 6. Longitudinal wave

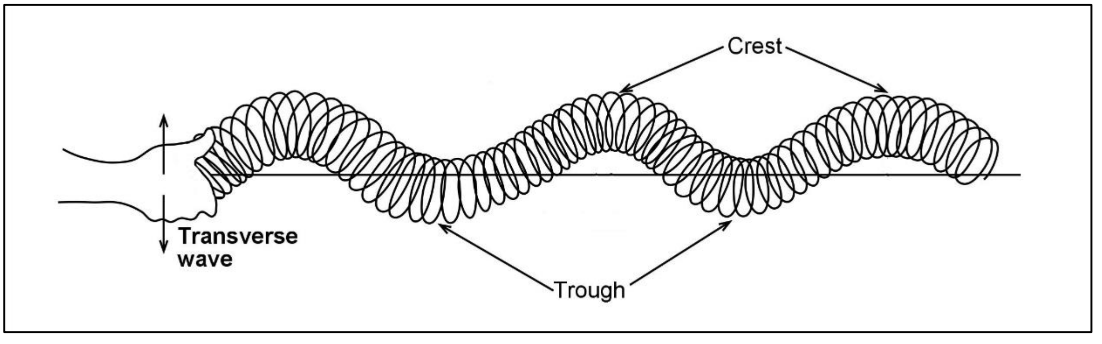


Figure 7. Transverse wave

Let us compare the longitudinal wave with the other kind of wave known as a transverse wave in Figure 7. The compressions resemble the trough while the rarefactions are the crests. Do you still remember these characteristics of waves? *The trough is the lowest part of a transverse wave while the crest is the highest portion*. The distance from one compression to the next or between two successive compressions in a longitudinal wave equals the **wavelength**. If you count the number of compressions passing by a certain point in 1 second, you are able to determine the **frequency** of the longitudinal wave. If you multiply the measured wavelength and the computed frequency you will be able to determine the speed of the wave. In equation,

$$v = f\lambda$$

There are other variations in the equation for the speed of the wave. The **period** of the longitudinal wave is the reciprocal of its frequency $\left[T = \frac{1}{f}\right]$. This means that the speed of the wave can be expressed as the ratio of the wavelength and the period,

$$v = \frac{\lambda}{T}$$

Let us try to compare the characteristics of longitudinal wave with that of the transverse wave in Activity 2.

Activity 2
Characteristics of waves: Comparing longitudinal and transverse waves

Objectives:

At the end of the activity, you will be able to:

1. distinguish the different characteristics of waves;
2. determine their frequency and wavelength; and
3. compute the wave speed based on the frequency and wavelength

Materials:

Pentel pen or permanent marker
stopwatch or mobile phone
meterstick
old calendar (big poster calendar) or old newspaper
metal slinky

Procedure:

1. Place the old calendar or old newspaper on the floor. Make sure that the newspaper or old calendar is long enough to accommodate the full length of the slinky spring.

2. Put the slinky on top of the old newspaper or old calendar. Ask one of your groupmates to hold one end of the slinky at the one end of the newspaper. This will serve as the *fixed end*.

3. Another groupmate will hold the other end of the slinky. This is the *movable end*.

4. The other members of the group should be along the sides so they can mark the corresponding crests. Identify a reference point **(point A)** along the slinky from which you are going to base your frequency count.

5. Shake the movable end. Apply just enough force to create large wave pulses. Make sure, however, that the *crest* and *trough* parts will still be formed within the newspaper area.

6. Another groupmate should count the number of pulses passing through point A in a minute. This is the *frequency* in waves per minute. You can convert this later to waves per second.

7. While your classmate is creating *transverse waves* by shaking the slinky, note by marking on the newspaper the crest and the trough of the created wave pulses.

8. Trace the wave form then measure the *wavelength* of the wave pulses. Record all your data on the answer sheet provided.

9. Repeat steps 5 to 8 for two more trials. Compute for the wave speed in each of the 3 trials. Determine also the average speed of the wave in the slinky.

10. For the second set up, repeat the whole procedure (steps 1 to 9) but this time instead of shaking the slinky, pull and push the slinky to create a longitudinal wave.

11. Note and mark the areas/regions in the newspaper where the slinky forms compressions and rarefactions.

12. Count the number of compressions passing through point A in a minute. This is the *frequency of the longitudinal wave in waves per minute*.

13. Measure the length between 2 compressions. This is the *wavelength of the longitudinal wave.*

14. Do this for three more trials, and then compute for the wave speed and the average speed of the wave in the slinky.

Q12. When there are more waves passing through the reference point in a period of time, which wave characteristic also increases?

Q13. When there are more waves passing through the reference point in a period of time, what happens to the wavelength of the waves?

As you have observed in Activity 2, there are many characteristics common to both transverse wave and longitudinal wave. The difference is in the motion of particles with respect to the direction of travel of the wave. Again, in a transverse wave, the movement of particles is perpendicular to the direction of wave travel. In a longitudinal wave, on the other hand, travel is parallel to the movement of the particles (Figure 8). In longitudinal waves, compressions are created when a push is applied on air. When air is pushed, there is a force applied on a unit area of air. From your science in the lower grades, the force applied per unit area is called **pressure**. This means that longitudinal waves are created by pressure and are also called *pressure waves*. Basically, sound as you have observed it is a longitudinal wave and a pressure wave. Just like the transverse waves, it has wave characteristics. Its movement is parallel to the particle motion. But do the particles in a way affect the movement of sound? What factors affect sound speed? Let us try finding this out in the next activities.

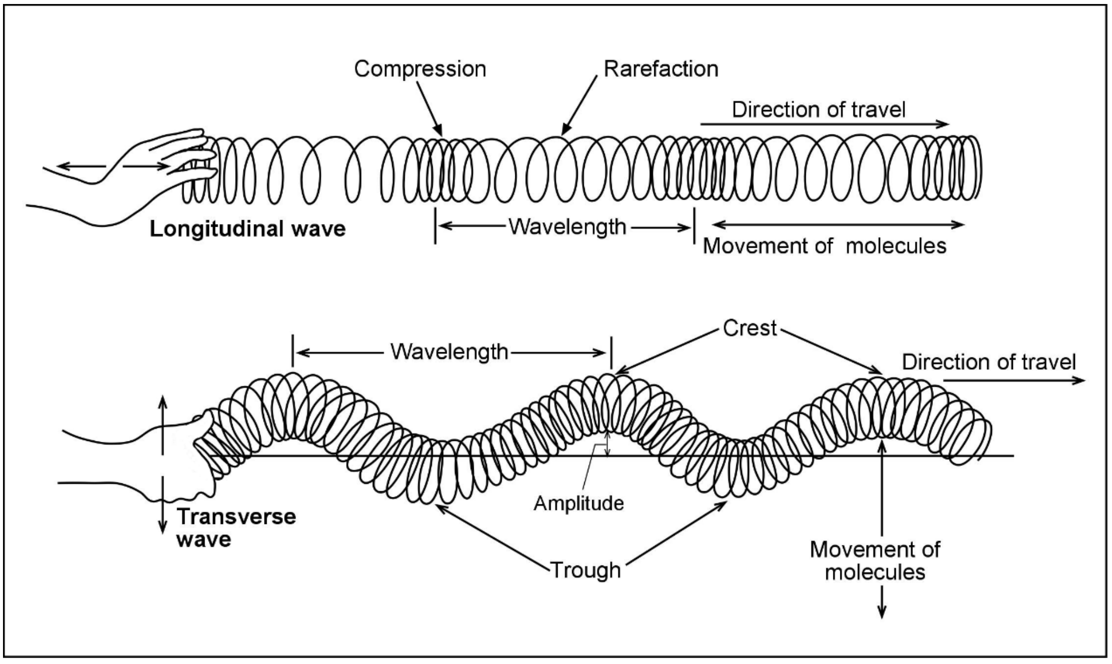


Figure 8. Transverse and longitudinal waves

Activity 3
Sound race...Where does sound travel fastest?

Objective:

At the end of the activity, you will be able to distinguish which material transmits sound the best.

Materials:

watch/clock that ticks
mobile phone
wooden dowel 80-100 cm long
metal rod 80-100 cm long
string (1 meter)
metal spoon
3 pieces zip lock bag (3x3) or waterproof mobile phone carrying case

Procedure:

1. Hold a ticking watch/clock as far away from your body as you can. Observe whether or not you can hear the ticking.

2. Press one end of the wooden dowel against the back part of the watch and the other end beside your ear. Listen very well to the ticking sound. Record your observations.

3. Repeat step #2 using a metal rod instead of the wooden dowel. Record your observations.

Q14. Did you hear the watch tick when you held it at arm's length? When you held it against the wooden dowel? When you held it against the metal rod?

4. Repeat steps #1 to #3 using a vibrating mobile phone instead. Record your observations.

Q15. Did you hear the mobile phone vibrate when you held it at arm's length? When you held it against the wooden dowel? When you held it against the metal rod?

5. Place the mobile phone in the waterproof carrying case and dip it in a basin of water while it vibrates.

Q16. Based on your observations, which is a better carrier of sound? Air or wood? Air or water? Air or metal? Water or metal?

6. At the center of the meter long string, tie the handle of the metal spoon. Hold the string at each end and knock the spoon against the table to make it ring or to create a sound. Listen to the ringing sound for a few seconds then press the ends of the strings against your ears. Observe and record the difference in sound with and without the string pressed against your ear.

7. Knock the spoon against the table. When you can no longer hear the sound of the ringing spoon, press the ends of the string against your ears. Record whether or not you could hear the ringing of the spoon again.

Q17. How did the sound of the spoon change when the string was held against your ears?

Q18. When the ringing of the spoon was too quiet to be heard through the air, could it be heard through the string?

Q19. Is the string a better carrier of sound than air?

So, through which material does sound travel fastest? Through which material did sound travel the slowest? Why does sound travel fastest in solids and slowest in air? Do you have any idea what makes sound move fast in solids?

Figure 9 shows a model for the three states of matter. Identify which is solid, liquid or gas. Now, do you have any hint why sound moves fastest in a solid medium? To give us a better picture of the differences of the three states of matter, consider worksheet 1. Then with the aid of Activity No.4 entitled *Chimes... Chimes... Chimes...* you will be able to determine what makes solid the best transmitter of sound.

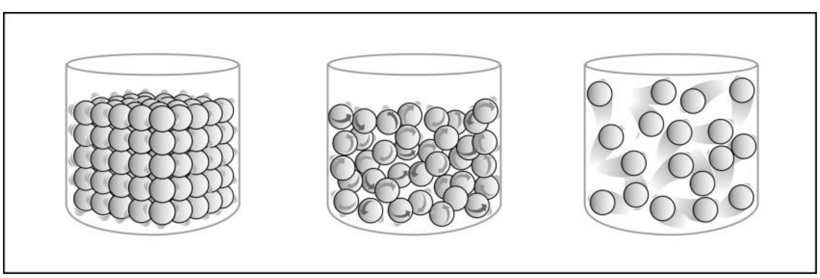


Figure 9. A model for the three states of matter

Worksheet 1: Solids, Liquids, & Gases

Direction: Using several resources and references, compare the different characteristics of solids, liquids, and gases by completing the table below.

Comparing Solids, Liquids, and Gases

Characteristics	Solid	Liquid	Gas
Intermolecular spacing			
Volume			
Ability to flow			
Compressibility			
Density			

Activity 4
Chimes… Chimes… Chimes…

Objective:

At the end of the activity, you will be able to infer using improvised chimes that closely spaced materials are the best transmitters of sound.

Materials:

materials for chime
nylon string or thread
plastic lid or wood about 1 ½ foot long
small electric fan
scissors
nail and hammer
beads
paint
iron stand

Procedure:

Improvised Chime

1. Go on a treasure hunt and look for items that will create a lovely sound when they collide, such as seashells, bells, beads, spoons, forks, and stones.

2. If the items are thin enough, poke a hole through them with a nail. Then pull a piece of string or nylon thread through each hole, and tie a knot.

3. For heavier objects, such as stones, spoons, or forks; wrap the string around the object a few times, and rub non-toxic liquid glue over the string to hold it in place.

4. Next, find a colorful plastic lid or a nice looking pieces of wood to serve as the top of the wind chime.

5. Tie at least 6 of these stringed objects on the plastic lid or on the wood. Make sure that the strands are evenly spaced and are not too far apart from each other.

6. Finally, tie another string at the two ends of the plastic lid or on the wood for hanging the chime.

Sounding the Chimes

1. Hang your chime in an iron stand where there is no wind source except your handy fan.

2. With the 6 stringed objects hanging on the wooden or plastic lid, switch on the fan and observe. This is your **CHIME 1**. Listen to the sound created by your chime. Ask one of your groupmates to move away from the chime until the sound is not heard anymore. Measure this distance from the chime to your groupmate and record your results.

3. Repeat step #2 but add 4 more stringed objects on the chimes creating chime with 10 stringed objects. Make sure that you tie the additional stringed objects in between the original ones. This is your **CHIME 2**.

Q20. With which chime did you record a longer distance?

Q21. Which chime had more stringed objects? Which chime had more closely spaced stringed objects given the same wooden lid?

4. Repeat step #2 but add 4 more stringed objects on the chime creating a chime with 14 stringed objects. This is your **CHIME 3.**

Q22. With which chime did you record the longest distance?

Q23. Which chime has the most stringed objects? Which chime has the most closely spaced stringed objects given the same wooden lid?

Q24. How would you relate the measured distance reached by the sound created by the chime and the spacing of the stringed objects in each of the 3 chimes?

Q25. Which chime is capable of transmitting sound the best?

Q26. How would you relate the distance of the stringed objects in the chime and the capability of the chime to transmit sound?

The speed of sound may differ for different types of solids, liquids, and gases. For one, the elastic properties are different for different materials. This property (elastic property) is the tendency of a material to maintain its shape and not deform when a force is applied to the object or medium. Steel for example will experience a smaller deformation than rubber when a force is applied to the materials. Steel is a rigid material while rubber can easily deform and is known as a flexible material.

At the molecular level, a rigid material is distinguished by atoms and/or particles with strong forces of attraction for each other. Particles that quickly return to their rest position can vibrate at higher speeds. Thus, sound can travel faster in mediums with higher elastic properties (like steel) than it can through solids like rubber, which have lower elastic properties.

Does the phase of matter affect the speed of sound? It actually has a large impact upon the elastic properties of a medium. Generally, the bond strength between particles is strongest in solid materials and is weakest in gases. Thus, sound waves travel faster in solids than in liquids, and faster in liquids than in gases. While the density of a medium also affects the speed of sound, the elastic properties have a greater influence on wave speed. Among solids, the most rigid would transmit sound faster. Just like the case of wood and metal in Activity 3.

What other factors may affect the speed of sound in a medium? What about temperature? Can the temperature of the medium affect how sound moves? Find out in the next activity.

Activity 5
Faster sound... In hotter or cooler?

Objective:

At the end of the activity, you will be able to determine how temperature affects the speed of sound.

Materials:

3 pieces 1000 mL graduated cylinders or tall containers
thermometer
bucket of ice
electric heater or alcohol lamp
tuning fork

Procedure:

1. Label the 3 graduated cylinders with HOT, ROOM TEMP, COLD respectively.

2. Half-fill the ROOM TEMP graduated cylinder with tap water.

3. Sound the tuning fork by striking it on the sole of your rubber shoes and hold it on top of the graduated cylinder.

4. When no loud sound is produced increase the amount of water up to a level where loud sound is produced when the vibrating tuning fork is placed on top. Note this level of water.

5. Fill the HOT graduated cylinder with hot water (about $70^{o}C$) to the same level as that of the ROOM TEMP cylinder.

6. Fill the COLD graduated cylinder with COLD water (about $5^{O}C$) at the same level as that of the ROOM TEMP cylinder.

7. Determine the temperature of the water in each of the cylinders just before sounding the tuning fork.

8. Sound the tuning fork in each of the cylinders and note the sound produced by each cylinder. Record all your observations.

9. Do this for three trials focusing on the differences in the pitch of the sound each cylinder creates. Record all your observations.

Q27. Which cylinder gave the loudest sound?

Q28. Which cylinder gave the highest pitched sound?

Q29. If pitch is directly dependent on frequency, then, which cylinder gives the highest frequency sound?

Q30. Since wave speed is directly dependent on frequency, then, which cylinder gives the fastest sound?

Q31. How would you relate the temperature of the medium with the speed of sound?

Now you know that the speed of sound is directly affected by the temperature of the medium. The hotter the medium the faster the sound travels. Heat, just like sound, is a form of kinetic energy. At higher temperatures, particles have more energy (kinetic) and thus, vibrate faster. And when particles vibrate faster, there will be more collisions per unit time. With more collisions per unit time, energy is transferred more efficiently resulting in sound traveling quickly. Sound travels at about 331 $\frac{m}{s}$ in dry air at 0^o C. The speed of sound is dependent on temperature of the medium where an increase is observed with an increase in temperature. This means that at temperatures greater than 0^oC speed of sound is greater than 331 $\frac{m}{s}$ by an amount $0.6\frac{m/s}{C}$ of the temperature of the medium. In equation,

$$v = 331\frac{m}{s} + 0.6\frac{m/s}{C}(T)$$

where T is the temperature of air in Celsius degree and $0.6\frac{m/s}{C}$ is a constant factor of temperature. Let's try it out at a room temperature of 25^oCelsius.

Sample Problem

Problem: What is the speed of sound in air of temperature 25°Celsius?

Solution:

Given: T = 25°Celsius

Equation: $v = 331\frac{m}{s} + 0.6\frac{m/s}{C}(T)$

Solution:

$$v = 331\frac{m}{s} + 0.6\frac{m/s}{C}(25)°C$$
$$v = 331\frac{m}{s} + 15\frac{m}{s}$$
$$v = 346\frac{m}{s}$$

Properties of Sound

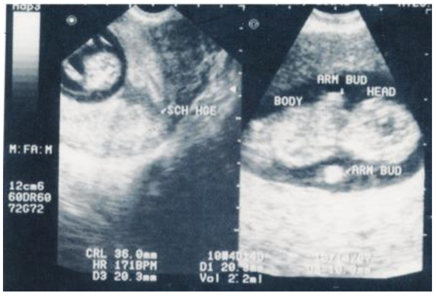


Figure 10. Ultrasound image

Figure 11. Live concert

Figures 10 and 11 are the amazing contribution of sound to other fields such as health, wellness and the arts particularly the music industry. We can experience or observe these as consequences of what are commonly called properties of sound waves. Ultrasound works on the principle of reflection of sound waves while concerts in open field benefit from refraction of sound. Want to know more about these amazing sound treats?

- **Reflection of Sound**

Figure 12. Bathroom singing

A lot of people love to sing inside the bathroom because of privacy. A study conducted noted that people would open their mouths wide when they sing in private places like the baths. Another reason is the hard wall surfaces of the bathroom usually made of wood or tiles brings about multiple reflection of sound. These hard walls or surfaces and the small dimension of the bathroom typically create an aurally pleasing acoustic environment with many echoes and reverberations contributing to the fullness and depth of voice. Well, this may not be the effect in the outside world though. Look at Figure 12 and try it yourself.

Just like any other wave, sound also exhibits reflection. Reflection is usually described as the turning back of a wave as it hits a barrier. **Echo** is an example of a *reflected sound*. **Reverberation** on the other hand refers to the *multiple reflections or echoes in a certain place*. A reverberation often occurs in a small room with height, width, and length dimensions of approximately 17 meters or less. This best fits the bathroom which enhances the voice.

In theaters and movie houses, there are also reverberations and echoes. But these are not pleasing to the ears during a play or a movie. To lessen these, designers use curtains and cloth cover for the chairs and carpets. Check out the different movie houses and look for features inside that decreases reverberations and echoes.

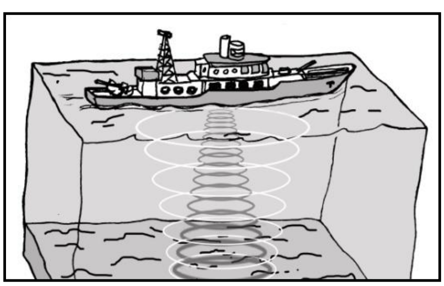


Figure 13. SONAR

Echo sounding is another application of sound reflection. This is used by scientists to map the sea floor and to determine the depth of the ocean or sea. This is just the same as how bats use sound to detect distances. What about you, can you identify other applications of sound reflection?

- **Refraction of Sound**

Have you ever wondered why open field concerts are usually held during nighttime? Having concert at night gives a chance for everyone to see and enjoy the live show because there is no work and no school. Sound also contributes to this scheduling of concerts. Usually, sound is heard better in far areas during nighttime than during daytime. This happens due to what is known as refraction. Refraction is described as the change in speed of sound when it encounters a medium of different density. As what you had earlier in this module, sound travels faster in hotter media. This change in speed of sound during refraction is also manifested as sort of "bending" of sound waves.

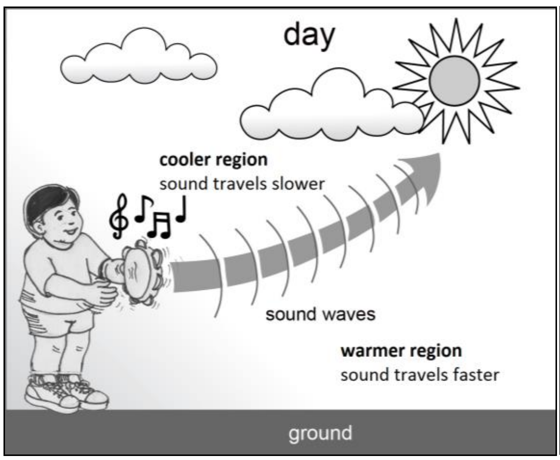


Figure14. Sound refraction at day time

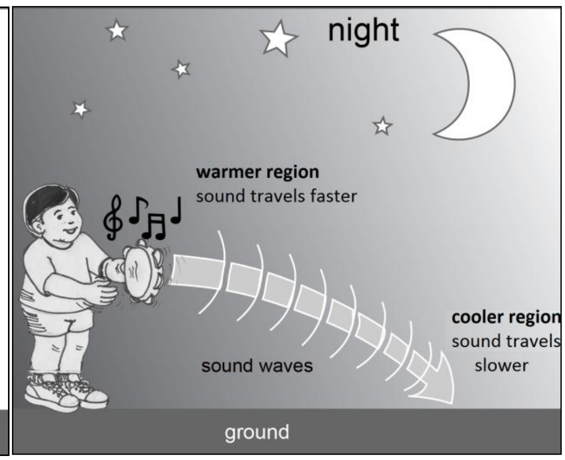


Figure15. Sound refraction at night time

When sound propagates in air, where the temperature changes with altitude, sound bends towards the hotter region. In this case, refraction happens. The refraction is due to the different refractive indices of air because of the difference in temperature. At daytime, when the sun is shining, the air near Earth's surface is cooler than the air above. From what you encountered in Activity 5, you learned that sound travels faster in hotter medium. Since Earth's surface is cooler than air above during daytime, then sound would move from the cooler region (Earth surface) towards the hotter air above. Thus, sound waves will be refracted to the sky (Figure 14). At night time, the air near the Earth's surface is heated by the heat emitted by the ground, making it hotter than the air above which is cooler due to the absence of the sun during nighttime. This makes sound move from the cooler air above towards the hotter air near the earth's surface. Thus, sound waves are refracted to the Earth's surface (Figure15). This makes open field concerts better done during nighttime as sound waves are refracted from the stage towards the audience. This gives a clearer and more audible music to enjoy.

Now on a more concrete sense let us try to observe how longitudinal waves reflect and refract. In Activity No. 6, you will be able to observe how reflection and refraction are exhibited by longitudinal waves using our metal slinky.

Activity 6
Reflecting and refracting sound

Objective:

At the end of the activity, you will be able to observe how longitudinal waves reflect and refract.

Materials:

metal slinky (large coil)
metal slinky (small coil)

Procedure:

Sound Reflection

1. Connect the *fixed end* to a wall or post. Make or create longitudinal waves by pushing and pulling the *movable end* part.

2. Observe the longitudinal waves as the waves hit the wall or post. Record your observations.

3. Note the positions of the compressions before they reach the post. Note also the locations or positions of the compressions after hitting the wall of the post.

4. Do this for 3 trials.

Q32. What happens to the compressions or rarefactions when they hit the wall or a fixed end?

Q33. Are the compressions found on the same location in the slinky before and after hitting the wall?

Q34. What happens to sound waves when they hit a fixed end or the wall?

Sound Refraction

1. Connect the *fixed end* of the metal slinky (small coil) to a wall or post. Then connect another slinky (large coil) to the other end of the small coil. Make or create longitudinal waves by pushing and pulling the *movable end* of the metal slinky (large coil).

2. Observe the longitudinal waves as the waves move from the large coil-metal slinky to the small coil metal slinky. Record your observations.

3. Observe the frequency, amplitude, and speed of the longitudinal waves as the waves move from the large coil metal slinky to the small coil metal slinky.

4. Do this for 3 trials.

Q35. What happens to the frequency of the longitudinal waves as the waves move from the large coil slinky to the small coil slinky?

Q36. What would be an observable change in sound when the frequency changes?

Q37. What happens to the amplitude of the longitudinal waves as the waves move from the large coil slinky to the small coil slinky?

Q38. What happens to sound when the amplitude of the sound changes?

Q39. What happens to the speed of the longitudinal waves as the waves move from the large coil slinky to the small coil slinky?

Summary

Sound waves are examples of longitudinal waves. They also exhibit characteristic features such as frequency, amplitude, wavelength, period and wave speed. The crest and the trough, however, are synonymous to compressions and rarefactions. These compressions and rarefactions are created when the particles of the medium are alternately pushed and pulled. The alternate pushing and pulling mechanically exerts force on unit areas of air particles and thus creating pressure waves. Compressions form when air particles or molecules of the medium are pushed creating lesser distance between particles, while rarefactions occur when the particles are somewhat pulled away from other particles creating a wider distance between particles. This alternating compressions and rarefaction make up the longitudinal waves like sound waves.

Just like other waves, the speed of a sound wave is determined by taking the product of the frequency and the wavelength. Speed of sound however is dependent on factors such as density and elasticity of the medium and temperature. The more elastic the medium is the faster the sound travels. Likewise, a direct relation is observed between temperature and sound speed.

Properties of waves such as reflection and refraction are also evident in sound waves. Reflected sound is known as an echo while repeated echo in a small dimension space or room is called reverberation. Change in speed resulting to bending of sound or refraction are usually observed with changes in temperature at certain altitude. What about transverse waves like light? Can we also observe these properties? Let's find out in the next module!

Links

Cheung Kai-chung (Translation by Yip Ying-kin). (n.d.). *Why do sound waves transmit farther at night? Is it because it is quieter at night?* Retrieved from http://www.hk-phy.org/iq/sound_night/sound_night_e.html

Gibbs, K. (2013). *The refraction of sound in hot and cold air*. Retrieved from http://www.schoolphysics.co.uk/age11-14/Sound/text/Refraction_of_sound/index.html

Suggested time allotment: 6 to 8 hours

Unit 1
MODULE
6

COLORS OF LIGHT

Overview

The Science of Light has gone all the way from a mere transfer of energy to the creation of colors for entertainment and other purposes. Most of our gadgets are light emitting for efficiency when used at night. In the field of medicine light is used to cut through the skin for surgery as in laparoscopy. The health sciences are also using light for other medical purposes. But the most important purpose is for humans and other animals to see the beautiful world through light. So, are you ready to explore the characteristics and properties of light?

In this module, you will learn some properties and characteristics of light. Among the characteristics and properties of light, we will focus on refraction and specifically, dispersion of light. We will try to find through simple activities how light disperse to form the colors of light. We will also try to find the hierarchy of colors of light in terms of frequency, wavelength, and energy. The different activities provided in this module will make us realize the beauty of everything with light.

How are refraction and dispersion demonstrated in light?

Among the different colors of light, which is bent the most and the least?

Why do we see spectacular events in the sky like rainbows, red sunset and blue sky?

Refraction of Light

Figure 1. Apparent depth … Refracted light

Did you know that the boy made the stunt in a 6-ft deep swimming pool? But as it appears in Figure 1 the water is just shallow and the stunt would not be dangerous at all. This optical illusion is known as apparent depth. Apparent depth is the illusion that objects under the water appear to be nearer the surface than they really are. This is visible when an observer is standing beside the swimming pool looking at an object under water. This phenomenon is a consequence of the bending of light when light traverses the air-water boundary.

Refracting Light

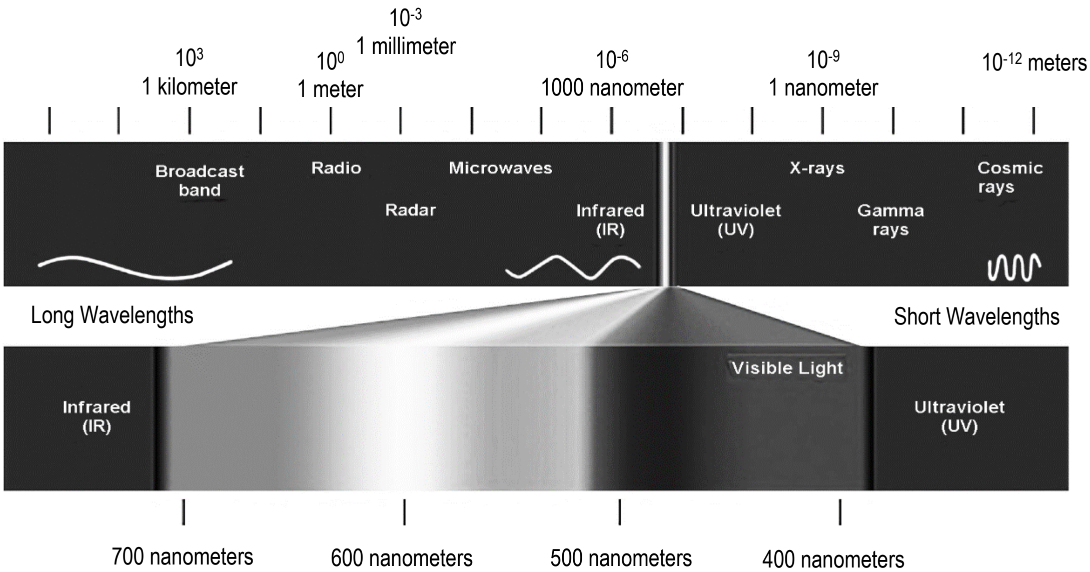


Figure 2. The Electromagnetic Spectrum

Light exhibits the characteristics and properties of a wave. It is classified as an electromagnetic wave located between the spectrum of infrared and ultraviolet. As an electromagnetic wave it does not need a medium in order to propagate. It moves in its maximum speed in vacuum. But this speed decreases as it moves along different media. This characteristic of light consequently shows bending when it crosses the boundary between two media. Apparent distortion of an object seen at the boundary between media is observed.

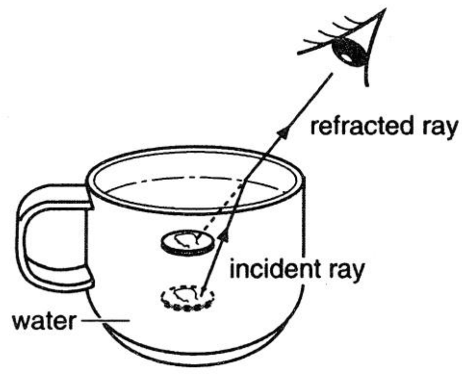


Figure 3. Show me the coin…

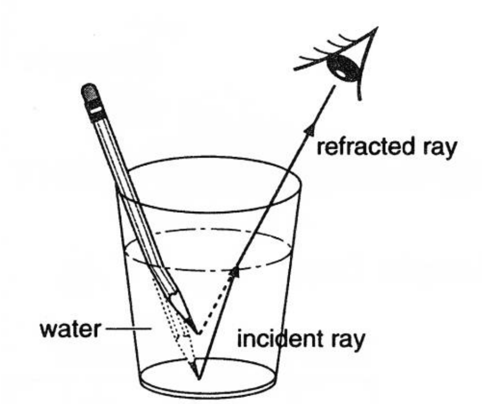


Figure 4. Broken pencil

Figures 3 and 4 are the basic examples of refraction of light. **Refraction** *is the bending of light when it travels from one medium to another of different optical densities*. The pencil as shown in Figure 4 is not really broken. If we remove the water from the glass and look at the pencil, the pencil would look normally straight. Now try pouring water onto the glass and, *voila* - a broken pencil. This happens because of the change in speed and orientation of the light with respect to the normal as it traverses a new medium of a different density.

Light travels so fast. From your lesson last year, it is approximated to travel at a speed of 3×10^8 m/s in a vacuum. This speed decreases when light travels in a dense medium. This means that the speed of light is dependent on the properties of the medium. In the case of light, it is dependent on the optical density of the medium. The optical density of the medium is different from its physical density. Physical density is described as the mass per unit volume of the medium. On the other hand, the sluggishness of the atoms of a medium to maintain the absorbed energy before reemitting it is called **optical density**. When light crosses the boundary of two media of different optical density, a change in speed takes place. This change in speed is manifested as bending of the light ray.

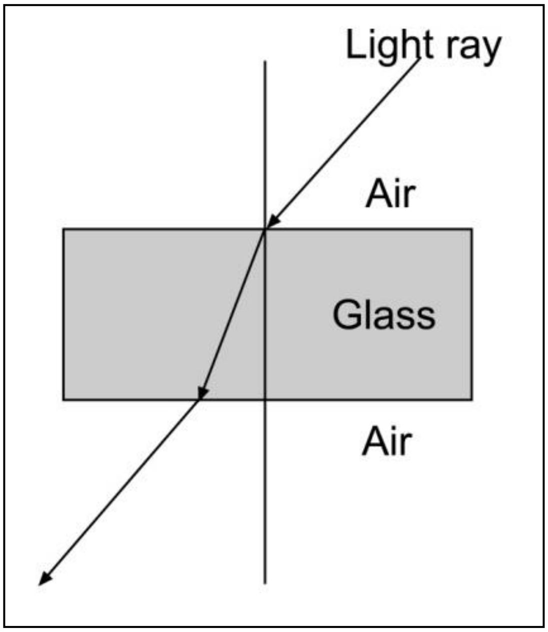


Figure 5. Refraction of light

In Figure 6, light travels from air to water. We observe that the ***incident angle (<i***) is greater than the ***angle of refraction (<r).*** We can see that the light ray refracts or bends towards the normal. Thus, light bends towards the normal when traveling from a less dense medium to a higher density medium.

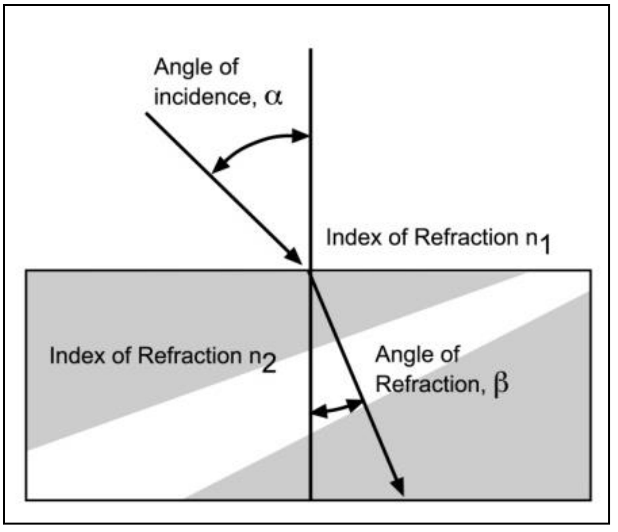


Figure 6. Refraction of Light in Water

A known indicator of the optical density of a material is the **index of refraction** of the material. Index of refraction represented by the symbol **n** is the ratio of the speed of light in vacuum and its speed in another medium. In symbols;

$$n = \frac{speed\ of\ light\ in\ vacuum}{speed\ of\ light\ in\ material} = \frac{C}{v}$$

The index of refraction of a material is a quantity that compares the speed of light in that material to its speed in a vacuum. Since the speed of light in vacuum is the highest attainable speed in the universe, the index of refraction is always greater than 1. The **n** values of other media are shown in Table 1.

Table 1. Index of refraction of other materials

Materials	Index of Refraction
Diamond	2.147
Zircon	1.923
Light flint glass	1.580
Crown glass	1.520
Ethyl alcohol	1.510
Water	1.360
Ice air	1.310
Vacuum	1.000

Activity 1
The colors of the rainbow...The colors of light

Objectives:

At the end of the activity, you will be able to infer that:

1. white light is made up of many different colors of light; and
2. each of these colors of light bends differently when it strikes objects like a prism.

Materials:

a sunny window
plastic container filled with water
2 sheets of white paper
a small mirror
penlight
prism
stack of books

Procedure:

Part A: ROY G. BIV on paper using a bowl of water

1. Place the bowl near the window. Make sure that there is plenty of sunlight in that part of the window.
2. Set the mirror partway into the water facing the light as shown in the figure on the right.
3. Hold the piece of paper up to intercept the reflected beam.
4. Adjust the position of the mirror until you see color bands on the piece of paper.

Q1. List and arrange the observed colors according to how they appear on the paper.

Part B: ROY G. BIV using a prism

1. Position a stack of books near the window where there is plenty of sunlight.

2. Place a white sheet of paper on top of the stack of books.

3. On top of this sheet place the prism. Make sure that sunlight from the window reaches the prism.

4. Position the prism until a rainbow or the colors of light appear on the white sheet of paper.

5. Use the table below to note the refractive indices of the colors of light in acrylic or crown glass

Material/Color of light	**λ(nm)**	**n**
Acrylic		
• Red	650	1.488
• Orange	600	1.490
• Yellow	550	1.497
• Green	500	1.495
• Blue	450	1.502
• Violet	400	1.508
Crown Glass		1.512
• Red	650	1.515
• Orange	600	1.518
• Yellow	550	1.520
• Green	500	1.525
• Blue Violet	440	1.530
	400	

6. Record all your observations in the worksheet provided.

Q2. Describe the position of the different colors after passing through the prism

Q3. Explain the dispersion of white light. Why is the prism or water able to separate the colors of white light?

Q4. Compare your results in the first part with your results in the second part. Are there any differences? What might account for the differences?

Q5. What did you observe with the indices of refraction of the colors of light in the acrylic prism?

Q6. How would this indices of refraction account for the arrangement of colors of light?

Were you able to get good sets of data from the activity? Did you enjoy watching how the rainbow colors appear when white light strikes the prism or the mirror in the bowl of water? We highlight here the arrangement of colors of light as ROYGBIV when dispersion happens. Again, *dispersion* is a special kind of refraction which provided us colors of light. This phenomenon is observed when white light passes through a triangular prism. When white light enters a prism, separation into different colors is observed. Remember the concept of refractive indices in the previous module and in the first part of the lesson? The refractive indices of the different colors of light indicate that light of different colors travels at different speeds in the prism which accounts for the different degrees of bending. Thus, blue light with greater refractive index refracts more and appears at the bottom of the red light. Activity 3, however, will give you a better idea why this is so.

Activity 2
Red versus violet...

Objectives:

At the end of the activity, you will be able to observe that bending depends on the refractive index of the color of light.

Materials:

2 sheets of white paper
a small mirror
flashlight
prism

Procedure:

1. Place or position two glass prisms on top of a white sheet of paper and near a white screen. It would be better if the white screen is positioned vertically.

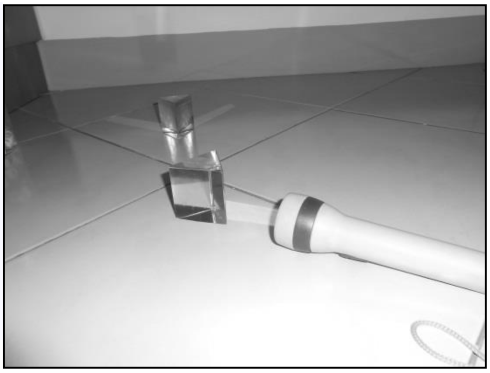
2. Position a flashlight on the other side of the prism. Switch on the flashlight and let the light strike the mirror.

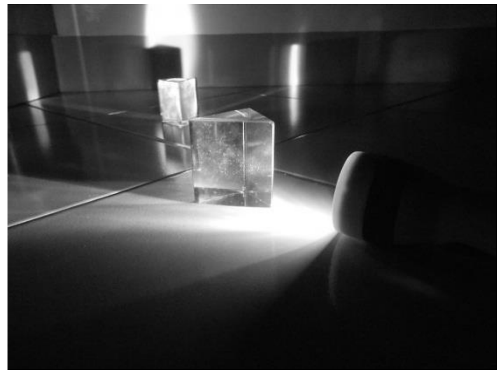
3. Make the necessary adjustment in the position of the prism or in the position of the flashlight until you observe a clear view of the different colors of light on the screen.

4. Mark the position of the colors of light on the white screen. Mark also the positions of the flashlight and the prism on the white sheet of paper.

5. Trace the light beam from the flashlight to the prism. Then trace the light ray from the prism to each of the colors of light on the white screen.

6. Draw line AO that bisects the prism located near the white screen vertically.





Q7. Did you observe the colors of light just as they appeared in the first activity?

Q8. How were these colors of light arranged on the white screen?

Q9. With respect to line AO, which among the colors of light on the white screen is most bent, red light or blue light?

Below is a table of wavelength and refractive indices of the color of light in a crown glass prism.

Material/Color of light	λ(nm)	n
Acrylic		
• Red	650	1.488
• Orange	600	1.490
• Yellow	550	1.497
• Green	500	1.495
• Blue	450	1.502
• Violet	400	1.508
Material/Color of light	**λ(nm)**	**n**
Crown Glass		
• Red	650	1.512
• Orange	600	1.515
• Yellow	550	1.518
• Green	500	1.520
• Blue	440	1.525
• Violet	400	1.530

Q10. How would you relate the refractive index with the bending of the color of light?

But what does the hierarchy of colors of light exhibit in terms of energy? Which color of light has the greatest energy? The next activity (Activity No. 4) will provide you with answers to this question. In this activity, you will be able to relate the hierarchy of colors and the hierarchy of the corresponding energy.

Activity 3
Which color has the MOST energy?

Objectives:

At the end of the activity, you will be able to infer that:

1. energy of the colors of light increases as one goes towards the right side of the color spectrum; and

2. red light has the least energy and blue light has the most energy.

Materials:

six (6) thermometers (special thermometers which are sensitive to small changes in temperature)
colored plastic (half sheets of Red, orange, yellow, green, blue and violet)
stapler
scissors
Scotch tape
string (nylon)
intense light source (if it is not sunny)

Procedure:

1. First, hang these thermometers in a shaded area. Wait for 10 minutes, then quickly observe and record the temperature shown by each thermometer. This will serve as the initial temperature of the thermometers. Wrap each thermometer with a different colored plastic. You may use Scotch tape to secure the thermometer.

2. Connect strings at the end part of the thermometer.

3. Then hang the thermometers with their respective wraps directly under the sun or an intense light source.

4. Record the temperature readings in each thermometer every five minutes.

Time Interval	**Temperature Readings (ºC)**					
	Red	***Orange***	***Yellow***	***Green***	***Blue***	***Violet***
Initial T						
Ist 5 min						
10 min						
15 min						
20 min						
25 min						
30 min						
Average						

Q11. Which thermometer registered the lowest temperature?

Q12. Which thermometer registered the highest temperature?

Q13. Which colored plastic allowed more energy to pass through it?

Q14. Which colored plastic allowed the least energy to pass through it?

Q15. From your answers in Q13 and Q14, which color of light has the least energy? The most energy?

Did you have a good set of results? Were you able to enjoy the activity on the energy of colors of light? Temperature as we have defined it in the previous module is the average kinetic energy of the molecules of an object. The higher the registered temperature, the greater is the average kinetic energy. When the violet colored wrapper is hit by sunlight or a light source, only the violet component of white light passes through the plastic. Since the thermometer wrapped in violet plastic registered the highest temperature, violet light then greatly increases the average kinetic energy of the air surrounding the thermometer. On the other hand, the thermometer with the red plastic cover only allows red light to pass through it. This means that since the thermometer covered with the red plastic sheet registered the lowest temperature, red light only brings about a minimal increase in the average kinetic energy of the air surrounding the thermometer. Basically, from Activity 3, we have identified that blue has the highest energy and red light has the least. On which other characteristics of color of light does the energy of the colors of light depend on?

Activity 4 revisits the activity you have already done in Grade 7. The focus of the activity in Grade 7 however, was to identify the corresponding frequency and wavelength of each color of light and the computation of the speed of each. We noted last time that the speed of the wave is the product of the frequency of the wave and the corresponding wavelength. This time we will focus on how energy relates to the frequency of the colors of light.

Activity 4
The color spectrum wheel revisited

Objectives:

At the end of the activity, you will be able to infer that:

1. light is composed of colors of different frequencies and wavelength;
2. the frequencies of the colors of light are inversely proportional to the wavelength;
3. the product of the frequency and the wavelength of the colors of light is a constant; and
4. the arrangement of colors of light shows the hierarchy of the color’s corresponding energy.

Materials:

Color Spectrum Wheel Pattern Cardboard or illustration board
white screen
button fastener
glue or paste

Procedure

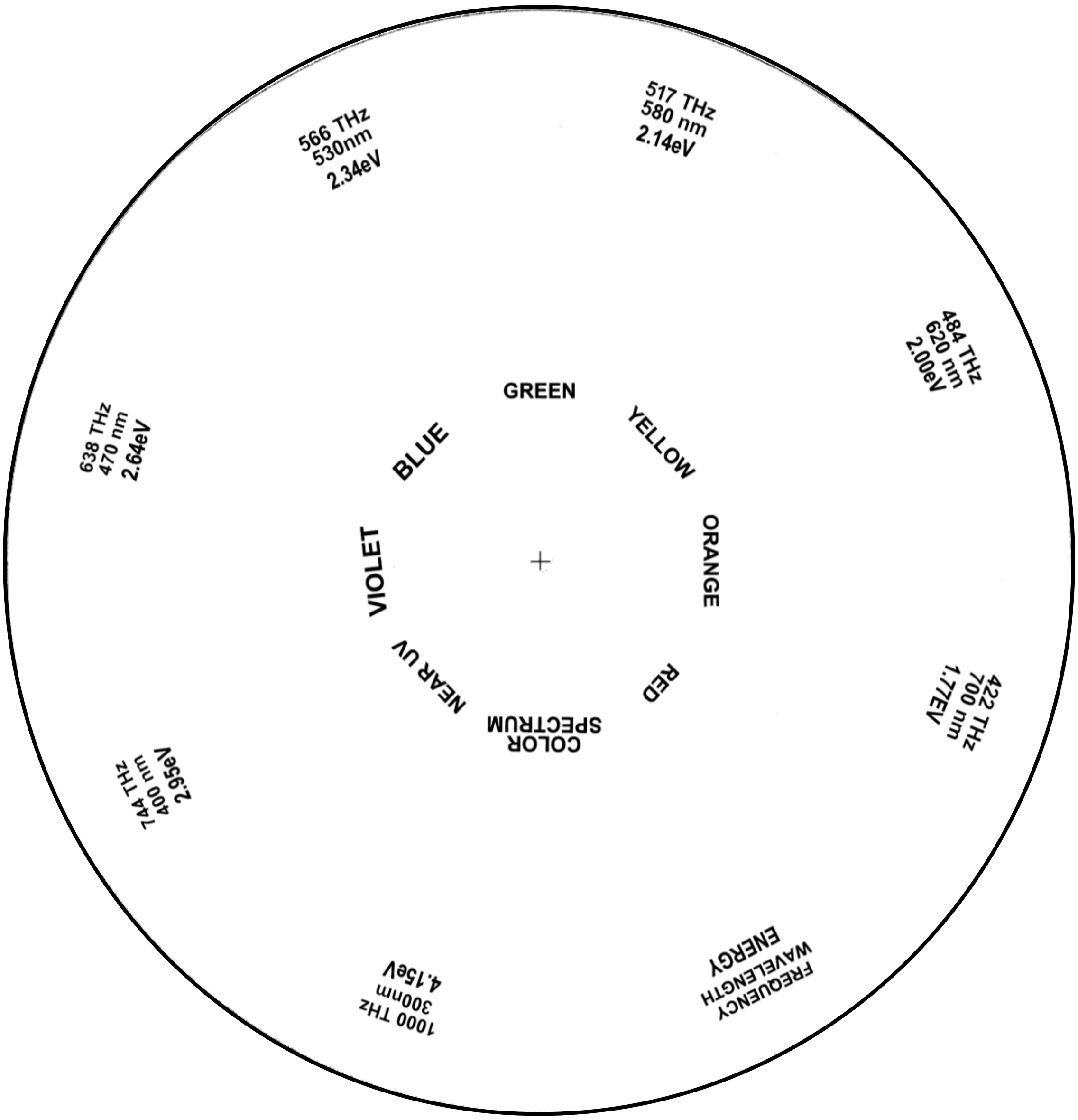
Part 1: Color Wheel

1. Cut the two art files that make up the wheel on the next pages.

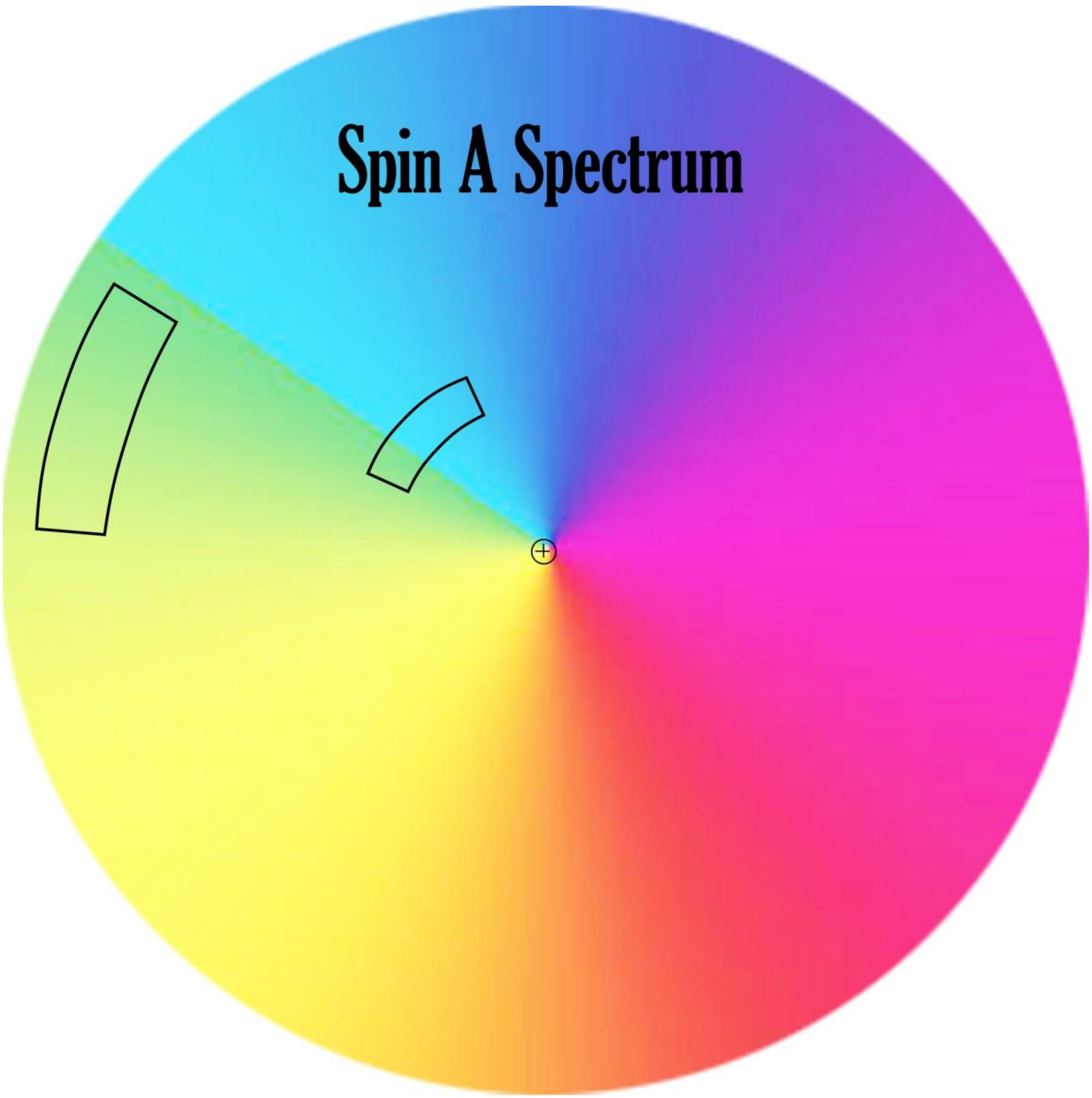
2. Cut along the lines drawn on the top wheel. Cut the 2 sides as shown. The small window near the center of the wheel should be completely cut out and removed.

3. Punch a hole at the center of the two wheels. You may use a button fastener to secure the two wheels together one on top of the other, but they should be free to rotate relative to each other.

4. When you see a region of the *color spectrum* show up in the open window and the "*W,F, E*" that correspond to that region showing up under the flaps, then you know that you have done it right.



517 THz
580 nm
2.14eV
566 THz
530nm
2.34eV
484 THz
620 nm
2.00eV
638 THz
470 nm
2.64eV
GREEN
BLUE
YELLOW
VIOLET
ORANGE
NEAR UV
RED
COLOR
SPECTRUM
422 THz
700 nm
1.77EV
744 THz
400 nm
2.95eV
1000 THz
300nm
4.15eV
FREQUENCY
WAVELENGTH
ENERGY


Spin A Spectrum

Part 2: Characteristics of Light

1. Try out your Color Spectrum Wheel by positioning the innermost of the flaps on COLOR SPECTRUM. This will simultaneously position the other flaps to WAVELENGTH, FREQUENCY, and ENERGY.

2. Turn the upper wheel and observe the combinations.

3. Fill in the table below with the corresponding combinations you have observed using your Spectrum Color Wheel.

	Frequency (Hz)	**Wavelength (m)**	**Frequency x wavelength**	**Energy (eV)**
Red				
Orange				
Yellow				
Green				
Blue				
Violet				

4. You will need to convert the equivalents of frequencies to Hz, the equivalent wavelengths to meters, and Joule to eV.

   Note the following equivalents:

   - *Terra (T) is a prefix for 10^{12} (1 THz = 1 x 10^{12} Hz)*
   - *nano (n) is a prefix equivalent to 10^{-9} (1 nm = 1 x 10^{-9} m)*
   - *1 eV = 1.6 x 10^{-19} Joule*

Q16. Which color registered the highest frequency? shortest wavelength?

Q17. Which color registered the lowest frequency? longest wavelength?

Q18. What did you observe about the wavelengths and frequencies of the different colors of light?

Q19. What did you observe about the products of frequencies and wavelengths?

Q20. Does the frequencies of the colors of light increase from Red to Violet?

Q21. What did you observe about the corresponding energies from Red to Violet?

Q22. How is frequency relate to energy of colors of light?

Now you have an idea why rainbows appear the way they do. Rainbows are created just like the colors of light appeared in Activity 1. A prism is needed to break the white light into the different colors of light. With the different refractive indices of the colors of light, bending is also different for each of the colors of light. From Activity 2 you have just found that Blue light is bent most. Thus, a rainbow starts with the RED light being at the topmost and ends with the VIOLET light being on the bottom of the bow? However, you saw the Blue at the bottom since Violet light is not very visible. But which acts as a prism in the sky for real large rainbows to form? Do you still believe that there is really a pot of gold at the end of the bow? There are many other beliefs about what we usually observe in the sky. Are these really true? Do they have scientific bases? Can you explain these phenomena? Let's try Activity 5.

Activity 5
Scientific explanations behind certain beliefs

Objectives:

At the end of the activity, you will be able to come up with a presentation of the scientific explanations of certain superstitious beliefs related to observable phenomena in the sky.

Materials:

interview guide
pen and paper

Procedure:

1. With your groupmates, draft about 5 questions that you intend to ask people so that you will be able to get information about your beliefs of the people in the locality regarding the following phenomena:

    a. Red sky in the afternoon (sunset)
    b. Why the sky is blue
    c. There's a pot of gold at the end of the rainbow

2. After writing the draft interview questions, have the questions checked by your teacher.

3. With the interview guide, visit old folks and conduct interviews.

4. Discuss with your groupmates the basic scientific explanations behind the superstitious beliefs. Complete the table in the worksheet.

5. You need to come up with a creative way of showing scientific explanations about the phenomena mentioned above in any form: electronic, play, or simulations.

Rubric Scoring Guide

CATEGORY	4	3	2	1
Presentation (50%)	Well-rehearsed with smooth delivery that holds audience attention. Explanations presented are easy to follow and there is no script reading or definition reading during the presentation. Props used are very useful during the presentation	Rehearsed with fairly smooth delivery that holds audience attention most of the time. Explanations presented are easy to follow and there is script reading or definition reading during the presentation.	Delivery not smooth, but able to maintain interest of the audience most of the time. Explanations presented not very easily understood and there is script reading or definition reading during the presentation.	Delivery not smooth and audience attention often lost. Explanations are very vague and the presenters settle with reading the whole presentation.
Interview Guide (15%)	Questions are very appropriate to determine information about superstitious beliefs of folks There are no grammatical of spelling errors.	Questions are appropriate to determine information about superstitious beliefs of folks There are few grammatical of spelling errors.	Questions are somewhat appropriate to determine information about superstitious beliefs of folks There are many grammatical of spelling errors.	Questions NOT appropriate to determine information about superstitious beliefs of folks There are many grammatical of spelling errors
Table of Superstitious beliefs and Scientific Explanation (35%)	Superstitious beliefs listed are empirically based. Scientific explanations are accurately stated	Most of the superstitious beliefs listed are empirically based. Scientific explanations are somewhat accurately stated	Some of the superstitious beliefs listed are empirically based. Scientific explanations are somewhat accurately stated	Almost all of the superstitious beliefs listed are empirically based. Scientific explanations not accurately stated. There are many misconceptions identified in the explanations

Summary

The dual nature of light brings about several observable phenomena in the sky. Light as a wave exhibits properties just like any other waves. When light moves from one medium to another of a different density, the speed changes, bringing about changes in the direction of the refracted ray with respect to the normal line. This is known as refraction. Refraction of light, however, may result in a display of colors of light when it passes through materials that can have varied refractive indices for every wavelength of color that passes through them. A glass prism, for example, has varied refractive indices per wavelength of color resulting in different bending angles of the refracted colors of light with respect to the normal line. This phenomenon is better known as dispersion.

With the concept of dispersion, colors of light are hierarchically arranged as ROYGBIV according to frequency and energy of the colors of light. Red happens to have the lowest frequency and the least energy. Energy and frequency increases as one moves from red light towards violet light. This display of colors of lights by dispersion of white light is one of the consequences of refraction of light aside from the apparent depth mentioned above. Other consequences are spectacular phenomenon of blue skies and red sunsets.

What other properties of light can be observed? Excited to know? These will be introduced to you at the next level! In the meantime, relax and enjoy the next module.

References and Links

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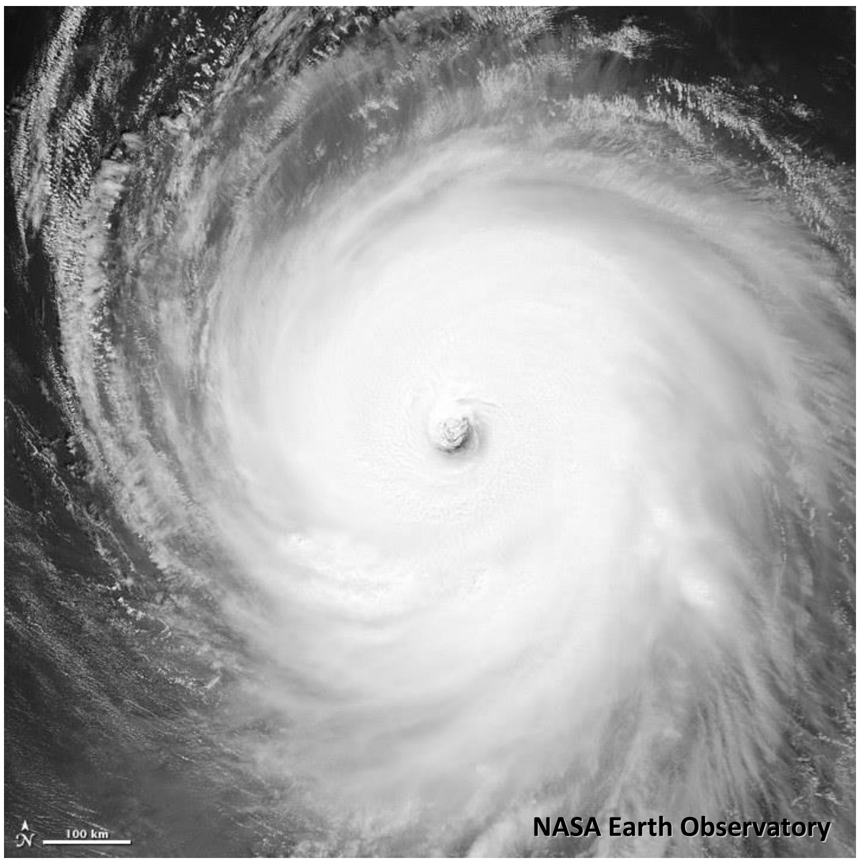
UNIT 2
Earth and Space



Suggested time allotment: 15 hours

Unit 2
MODULE
1

EARTHQUAKES AND FAULTS

Overview

If you recall, it was mentioned in Grade 7 that the Philippines is located along the Ring of Fire. How does this affect us? People who live along the Ring of Fire have to put up with earthquakes and volcanic eruptions. In this module, we will focus on earthquakes.

An earthquake is one of the most frightening things that anyone can ever experience. You grow up believing that the Earth is rock solid and steady. But then the ground suddenly shakes and you do not know what to believe anymore.

Strong earthquakes have caused countless deaths all over the world, even before people have started recording these events. No wonder scientists have been working very hard to find a way to predict when an earthquake occurs.

No one can stop quakes from happening. But there are things that people can do to avoid or reduce loss of life and damage to property. The first step is to have a clear understanding of the occurrence of earthquakes.

Why do earthquakes occur?

What is the relationship between earthquakes and faults?

What is a Fault?

On July 16, 1990, a strong earthquake hit Luzon. Have you heard about it? Maybe not, because it happened before you were born. But if your parents are from Luzon, they surely know about the earthquake. It is possible that they were even affected by it.

During that earthquake, many people lost their lives and many more were injured. A lot of buildings and other structures were either damaged or destroyed. The earthquake had a magnitude of 7.8 and its epicenter was located in Nueva Ecija. According to scientists, the earthquake was caused by movement along the Philippine Fault.

Fault, *epicenter*, *magnitude.* Do you know what these terms mean? You will learn about them in this module. Let us start with faults.

Earthquakes are associated with faults. When a fault suddenly moves, an earthquake occurs. Do you know what a fault is? Do the following activity to find out.

Activity 1
A fault-y setup

Objectives:

After performing this activity, you should be able to:

1. describe the appearance of a fault; and
2. explain how a fault forms.

Materials Needed:

two sheets of cardboard (or folder)
fine sand
ruler
newspaper (or plastic sheet) as wide as a newspaper page

Procedure:

1. Spread the newspaper on a table. Do the activity on the newspaper.

2. Arrange the two sheets of cardboard edge to edge (Figure 1).

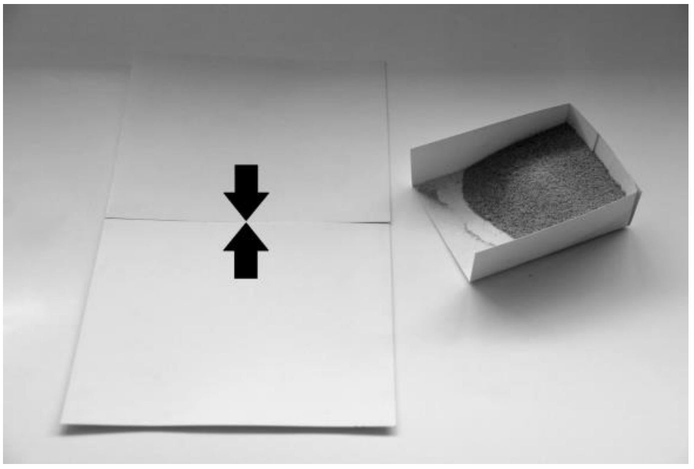


Figure 1. Cardboard sheets placed side by side.

3. Pour sand along the boundary of the two sheets (Figure 2).

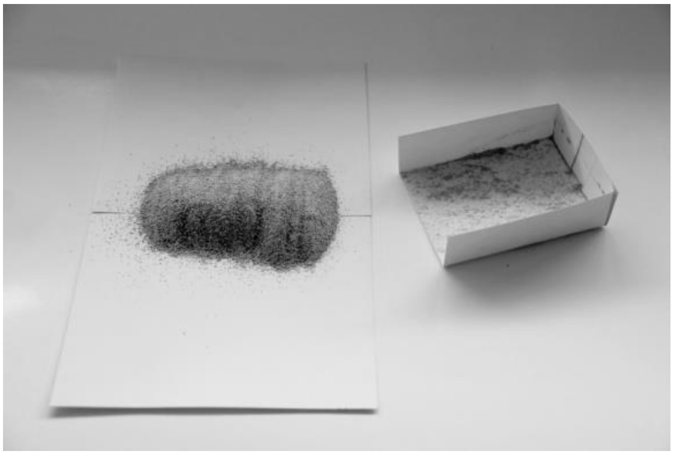


Figure 2. Sand along the boundary.

4. With the ruler, flatten the top of the sand and make two parallel lines.

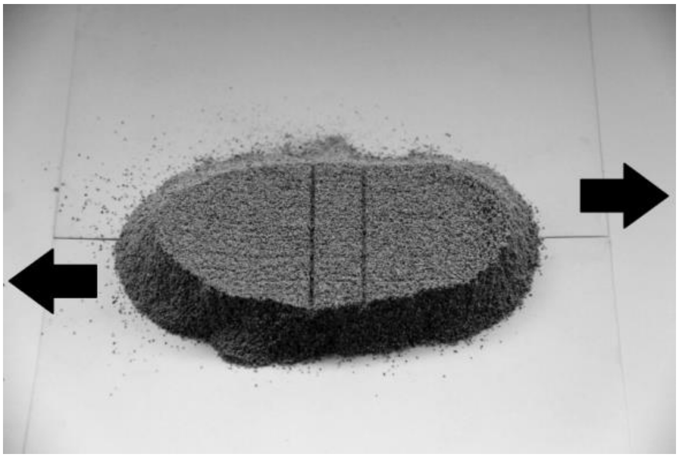


Figure 3. Top of sand flattened.

5. Now, move the sheets slowly in the direction shown in Figure 3.

Q1. As you move the sheets, what is formed in the sand?

Q2. What happens to the lines?

Now, study Figure 4. Do you see anything unusual?

Figure 4. Can you spot the fault? (Image courtesy of the GEER Association and National Science Foundation)

If you look at the picture carefully, you can guess that the road was originally in one piece. But the road is no longer continuous. There is a cut across the road and now there are two sections. One section has moved with respect to the other.

Compare what you see in the picture and what you saw in the activity. Is there something in the picture that looks like what was formed in the activity? Do you see anything similar?

Based on the activity and the picture, you can probably guess what a fault is by now. A fault is a break in the Earth's crust, and along the break, significant movement has taken place.

How do Faults Produce Quakes?

In the following activity, you will learn how earthquakes are related to faults.

Activity 2.
Stick 'n' slip

Objectives:

After performing this activity, you should be able to:

1. explain how faults generate earthquakes; and
2. explain why not all movement along faults produces earthquakes.

Materials Needed:

two small boxes (fruit juice boxes are ideal)
masking tape
rubber band
paper clip

Procedure:

1. Attach the rubber band to the paper clip. Then attach the paper clip to one end of one box. (See Figure 5. The ruler is included for scale.)

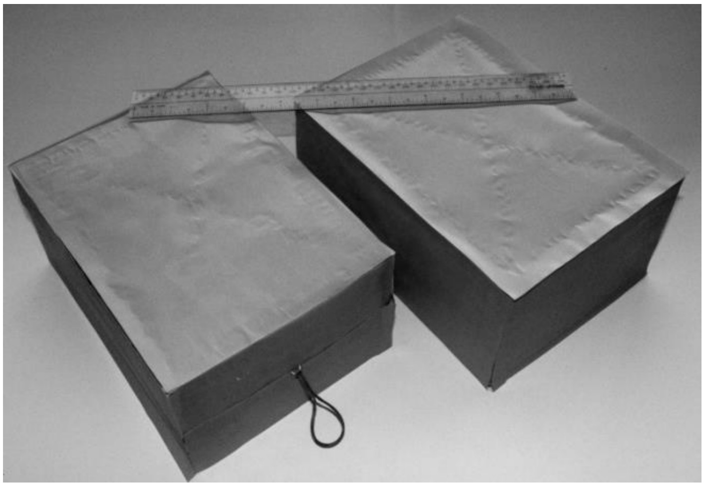


Figure 5. Two boxes - one with a rubber band attached to a paper clip

2. Place the boxes side by side. Put a toy house on the box with the rubber band. Then tape (lightly?) the two boxes together as shown in Figure 6. Important: Do not stick the tape on the boxes too much. The tape is meant to come off.

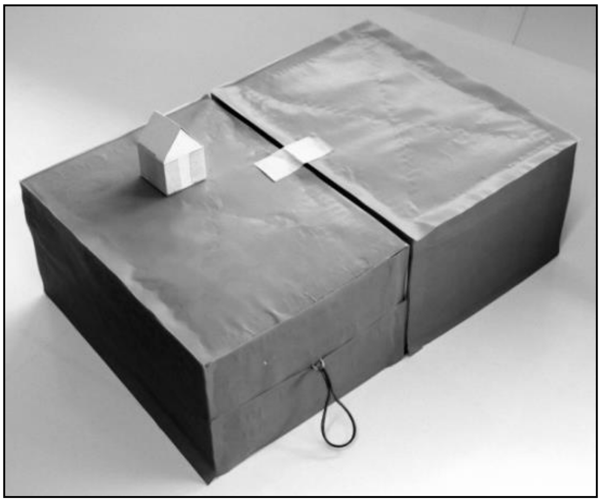


Figure 6. Two boxes side by side and lightly taped. Toy house on top of box with rubber band)

Figure 7. Rubber band on box with toy house pulled slowly. Observe what happens.

3. With your left hand, hold the box without the rubber band in place. With your other hand, slowly pull on the rubber band in the direction shown in Figure 7.

Q3. What happens to the rubber band?

Q4. Keep on pulling on the rubber band. What happens to the box attached to the rubber band? Note: The tape is supposed to come off, so stick it on very lightly.

Q5. What happens to the "house"?

Q6. Which is the "fault" in this setup?

Imagine the boxes as the ground, and the boundary between them as a fault. Energy from inside the Earth makes the ground move. You simulate this by pulling on the rubber band. There is no movement right away because of friction. (What represents friction in the activity?)

Once friction is overcome, the ground suddenly moves and an earthquake occurs. Some scientists describe this process as *stick and slip*. At first, the rocks are stuck together due to friction. Later, the rocks suddenly slip, generating an earthquake. Every time a fault slips, the Earth quakes.

In the activity, there was a sudden jerk, but no shaking. The boxes did not shake as in a real earthquake. Let us see what the next model does (shows?).

Activity 3.
Stick 'n' shake

Objectives:

After performing this activity, you should be able to:

1. explain the effect of bending of rocks along faults, and

2. relate faults movement and earthquakes

Materials Needed:

two plastic rulers
a bit of clay

Procedure:

1. Using the clay, attach the rulers' ends together (how long is the overlap between rulers?) (Figure 8 shows closeup photos of side and top views of the setup.)

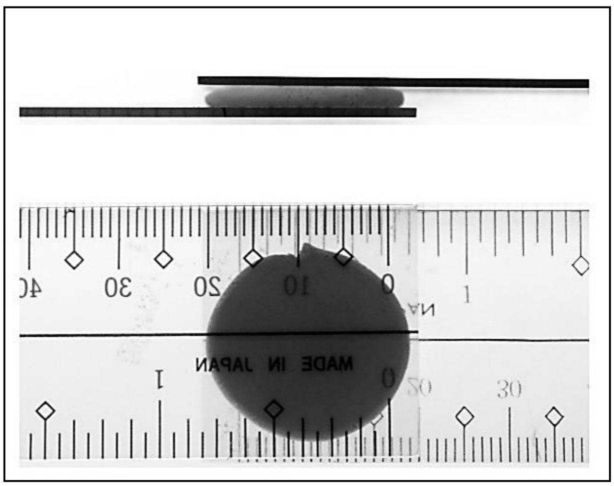


Figure 8. Side view and top view of setup.

2. Hold the rulers as shown in the picture below. Then slowly move your hands in the direction of the arrows.

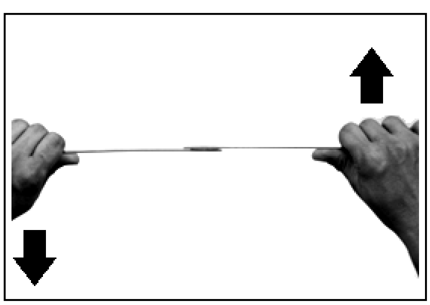


Figure 9. Right hand pushes (arrow up) while left hand pulls (arrow down)

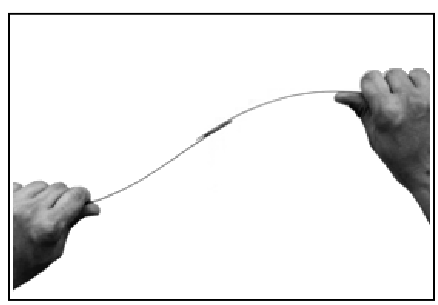


Figure 10. What is stored in the bent rulers?

Q8. What happens when bending becomes too much? Note: If nothing happens, separate the rulers and re-attach them only slightly.

The activity you just performed simulates how rocks bend along a fault. Think of the rulers as if they were part of the ground. Figure 11 can help you visualize this.

Drawing A shows how the rocks look at first. Then energy from inside the Earth makes the rocks bend (Drawing B). But as mentioned earlier, the rocks along the fault do not move immediately. Friction keeps them in place. (In the activity, what represents friction?)

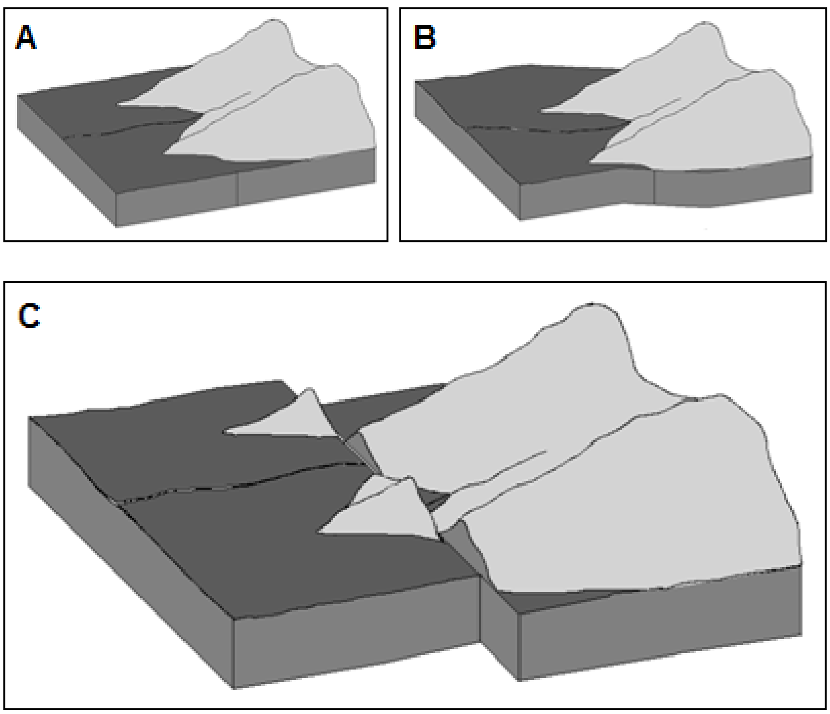


Figure 11. Drawing A shows the ground before bending. In Drawing B, the ground is bending, storing energy. In Drawing C, the bending limit is reached, and the ground has snapped.

When too much bending occurs and the limit is reached, the rocks suddenly snap (Drawing C). The bent rocks straighten out and vibrate. The vibrations travel in all directions and people in different places will feel them as a quake. An earthquake is a vibration of the Earth due to the rapid release of energy.

Focus and Epicenter

Now that you know the relationship between faults and earthquakes, it is time to get to know the meaning of terms used when earthquakes are reported in the news.

Activity 4.
Where does an earthquake start?

Objectives:

After performing this activity, you should be able to:

1. differentiate between focus and epicenter; and
2. demonstrate how movement along faults affect the surroundings.

Materials Needed:

fault model
scissors
paste

Procedure:

1. Photocopy the Fault Model (Figure 12; you can also trace it on paper). Then cut along the outlines of the two drawings.
2. Fold along the lines and paste where indicated. In the end, you should have a model consisting of two parts that fit together (Figure 13).
3. The upper surface of the model represents the surface of the Earth. The trace of the fault on the surface of the Earth is called the *fault line.* Be ready to point out the fault line when your teacher calls on you.
4. Pull the two pieces apart (Figure 14). The flat surface between the two pieces is called the *fault plane*. This is where fault slip or fault movement happens. Point out the fault plane when your teacher asks you.
5. The place where the fault begins to slip is called the *focus*. It is where the first movement occurs. Thus, the focus is the origin of the earthquake. Be ready to explain it to your teacher.

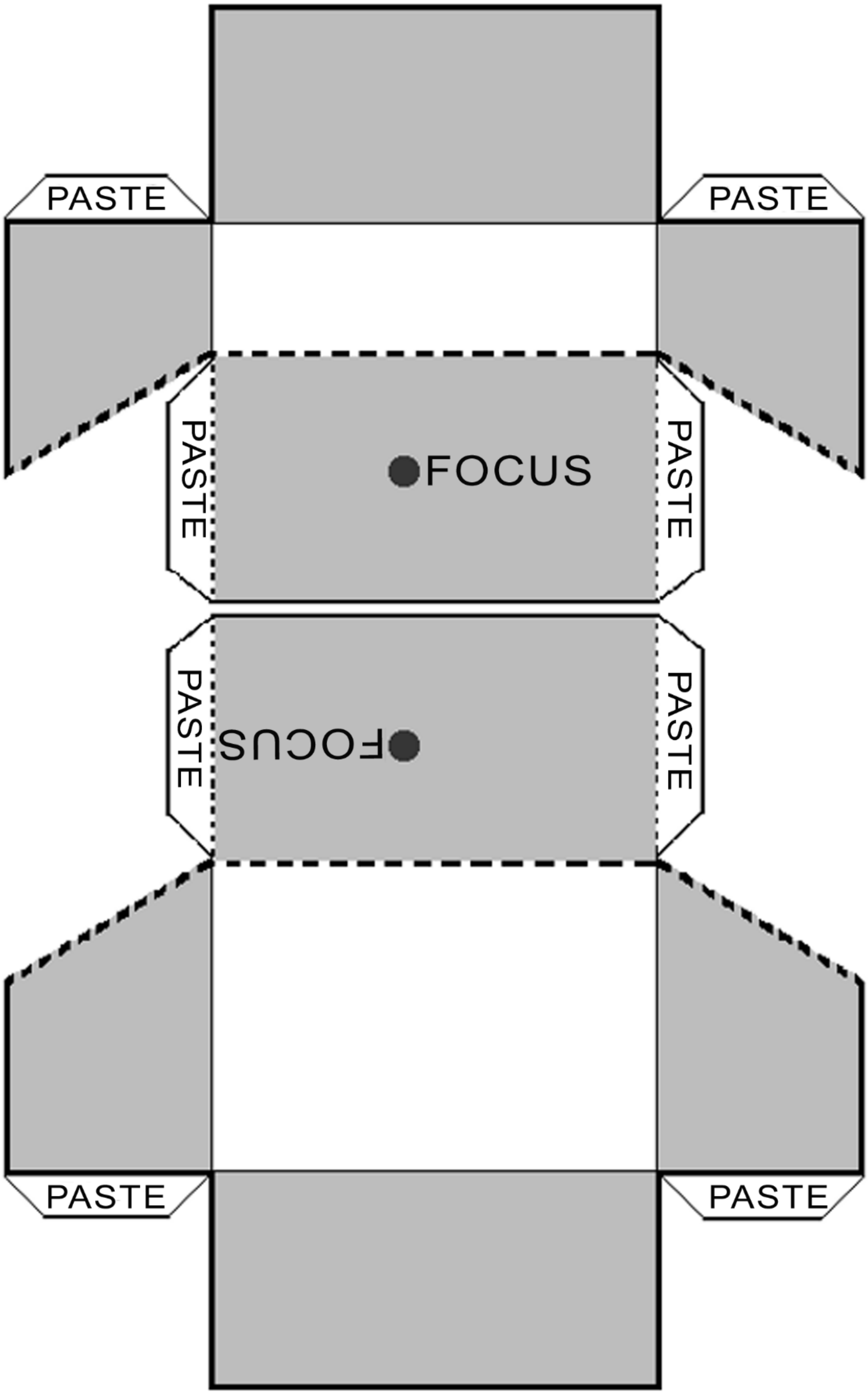


Figure 12. Fault Model

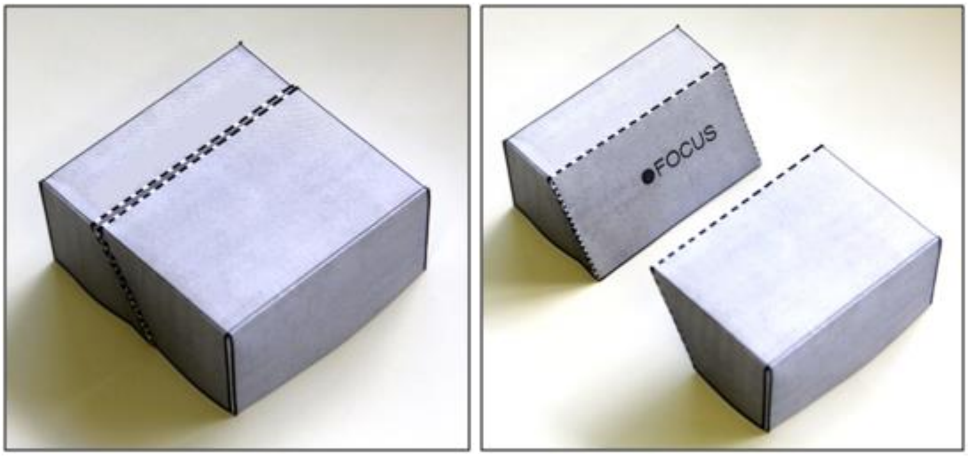


Figure 13. (Left) The fault model is made of two parts that fit together. (Right) The flat surface between the two parts represents the fault plane.

6. Put the two pieces of the model together. The focus is now hidden "underground." Now, imagine a vertical line from the focus to the upper surface of the model. Mark the place where you expect the line to come out.

   The spot directly above the focus on the surface of the Earth is called the *epicenter.* Show the "epicenter" of your model to your teacher.

Q9. Use your model to show different types of movement along a fault. How would the surroundings be affected?

How Strong is the Earthquake?

An earthquake may be described in two ways: intensity and magnitude. The intensity of an earthquake gives us an idea of how strong or weak the shaking is. The Philippine Institute of Volcanology and Seismology (PHIVOLCS) uses the following scale to describe the intensity of earthquakes in the Philippines.

Table 1. PHIVOLCS Earthquake Intensity Scale (PEIS)

Intensity Scale	Description
I	**Scarcely Perceptible** - Perceptible to people under favorable circumstances. Delicately balanced objects are disturbed slightly. Still water in containers oscillates slowly.
II	**Slightly Felt** - Felt by few individuals at rest indoors. Hanging objects swing slightly. Still water in containers oscillates noticeably.
III	**Weak** - Felt by many people indoors especially in upper floors of buildings. Vibration is felt like one passing of a light truck. Dizziness and nausea are experienced by some people. Hanging objects swing moderately. Still water in containers oscillates moderately.
IV	**Moderately Strong** - Felt generally by people indoors and by some people outdoors. Light sleepers are awakened. Vibration is felt like a passing of heavy truck. Hanging objects swing considerably. Dinner, plates, glasses, windows, and doors rattle. Floors and walls of wood framed buildings creak. Standing motor cars may rock slightly. Liquids in containers are slightly disturbed. Water in containers oscillate strongly. Rumbling sound may sometimes be heard.
V	**Strong** - Generally felt by most people indoors and outdoors. Many sleeping people are awakened. Some are frightened, some run outdoors. Strong shaking and rocking felt throughout building. Hanging objects swing violently. Dining utensils clatter and clink; some are broken. Small, light and unstable objects may fall or overturn. Liquids spill from filled open containers. Standing vehicles rock noticeably. Shaking of leaves and twigs of trees are noticeable.
VI	**Very Strong** - Many people are frightened; many run outdoors. Some people lose their balance. Motorists feel like driving in flat tires. Heavy objects or furniture move or may be shifted. Small church bells may ring. Wall plaster may crack. Very old or poorly built houses and man-made structures are slightly damaged though well-built structures are not affected. Limited rockfalls and rolling boulders occur in hilly to mountainous areas and escarpments. Trees are noticeably shaken.

VII	**Destructive** - Most people are frightened and run outdoors. People find it difficult to stand in upper floors. Heavy objects and furniture overturn or topple. Big church bells may ring. Old or poorly-built structures suffer considerably damage. Some well-built structures are slightly damaged. Some cracks may appear on dikes, fish ponds, road surface, or concrete hollow block walls. Limited liquefaction, lateral spreading and landslides are observed. Trees are shaken strongly. (Liquefaction is a process by which loose saturated sand lose strength during an earthquake and behave like liquid).
VIII	**Very Destructive** - People are panicky. People find it difficult to stand even outdoors. Many well-built buildings are considerably damaged. Concrete dikes and foundation of bridges are destroyed by ground settling or toppling. Railway tracks are bent or broken. Tombstones may be displaced, twisted or overturned. Utility posts, towers and monuments may tilt or topple. Water and sewer pipes may be bent, twisted or broken. Liquefaction and lateral spreading cause man-made structure to sink, tilt or topple. Numerous landslides and rockfalls occur in mountainous and hilly areas. Boulders are thrown out from their positions particularly near the epicenter. Fissures and faults rupture may be observed. Trees are violently shaken. Water splash or slop over dikes or banks of rivers.
IX	**Devastating** - People are forcibly thrown to ground. Many cry and shake with fear. Most buildings are totally damaged. Bridges and elevated concrete structures are toppled or destroyed. Numerous utility posts, towers and monument are tilted, toppled or broken. Water sewer pipes are bent, twisted or broken. Landslides and liquefaction with lateral spreadings and sandboils are widespread. the ground is distorted into undulations. Trees are shaken very violently with some toppled or broken. Boulders are commonly thrown out. River water splashes violently or slops over dikes and banks.
X	**Completely Devastating** - Practically all man-made structures are destroyed. Massive landslides and liquefaction, large scale subsidence and uplift of land forms and many ground fissures are observed. Changes in river courses and destructive seiches in large lakes occur. Many trees are toppled, broken and uprooted.

The intensity of an earthquake is determined by observing the effects of the earthquake in different places. Houses, buildings, and other structures are inspected. People are interviewed about what they saw (the cabinet fell over), how they felt (I was frightened), or what they did (I ran out of the house).

Now, do the following thought exercise. Suppose an earthquake occurred in Luzon. Would the intensity be the same all over the Philippines? Before you tackle this question, try answering the following first:

A) When an earthquake occurs, where would shaking be greater? Near the epicenter or away from the epicenter?

B) Where would damage be more? Near the epicenter or away from the epicenter?

C) Based on your answers to Questions A and B, where would the intensity be higher? Near the epicenter or away from the epicenter?

Another way of describing the strength of an earthquake is by magnitude. Recall that as rocks bend along a fault, energy is stored little by little. When the rocks suddenly snap, the stored energy is released.

The released energy can be calculated by scientists and is called the magnitude of the earthquake. Obviously, the greater the magnitude, the stronger the earthquake. To distinguish the two, intensity is expressed using Roman numerals (I, II, III) while magnitude uses Hindu-Arabic numerals (2, 3, 4).

Earthquakes with a magnitude of 2 may or may not be felt. Those that are felt by most people have a magnitude of 4. Magnitude 6 quakes can lead to a lot of damage in highly populated areas.

Earthquakes with a magnitude of 7 can cause severe damage. A magnitude 8 or 9 quake results in widespread destruction, especially near the epicenter. Luckily, only one or two occur every year.

Do You Live Near an Active Fault?

An active fault is one that has moved in the past and is expected to move again. Put in another way, an active fault has generated earthquakes before and is capable of causing more in the future.

Scientists use different ways to find out if a fault is active. One is by checking the country's historical records. Historians always write about destructive events such as earthquakes.

Another is by studying the vibrations, past and present, that come from faults. Still another way is by observing the surroundings. For example, a fault may cross a road and because of that, the road is displaced.

Or a fault may cut across a stream and the stream channel is then shifted. Or a fault may slice through mountains and form cliffs. This is not to say that anyone can spot an active fault. Scientists need a lot of training to do that.

But along some faults, the effects may be dramatic. Suppose a house was built on a fault. As the ground shifts little by little, parts of the house will be affected. The floor will crack, doors will not close, and the roof may start to leak.

Obviously, it is important to know the location of active faults. As far as possible, no important structures should be built near or on them. PHIVOLCS has a map that shows the active faults in the Philippines (Figure 14).

(In the map, the lines with triangles are trenches, another source of earthquakes. Trenches will be discussed in Grade 10.)

Study the map and find out where you live. Is there an active fault passing by your town, province, or region? If so, are you and your family prepared for the occurrence of an earthquake?

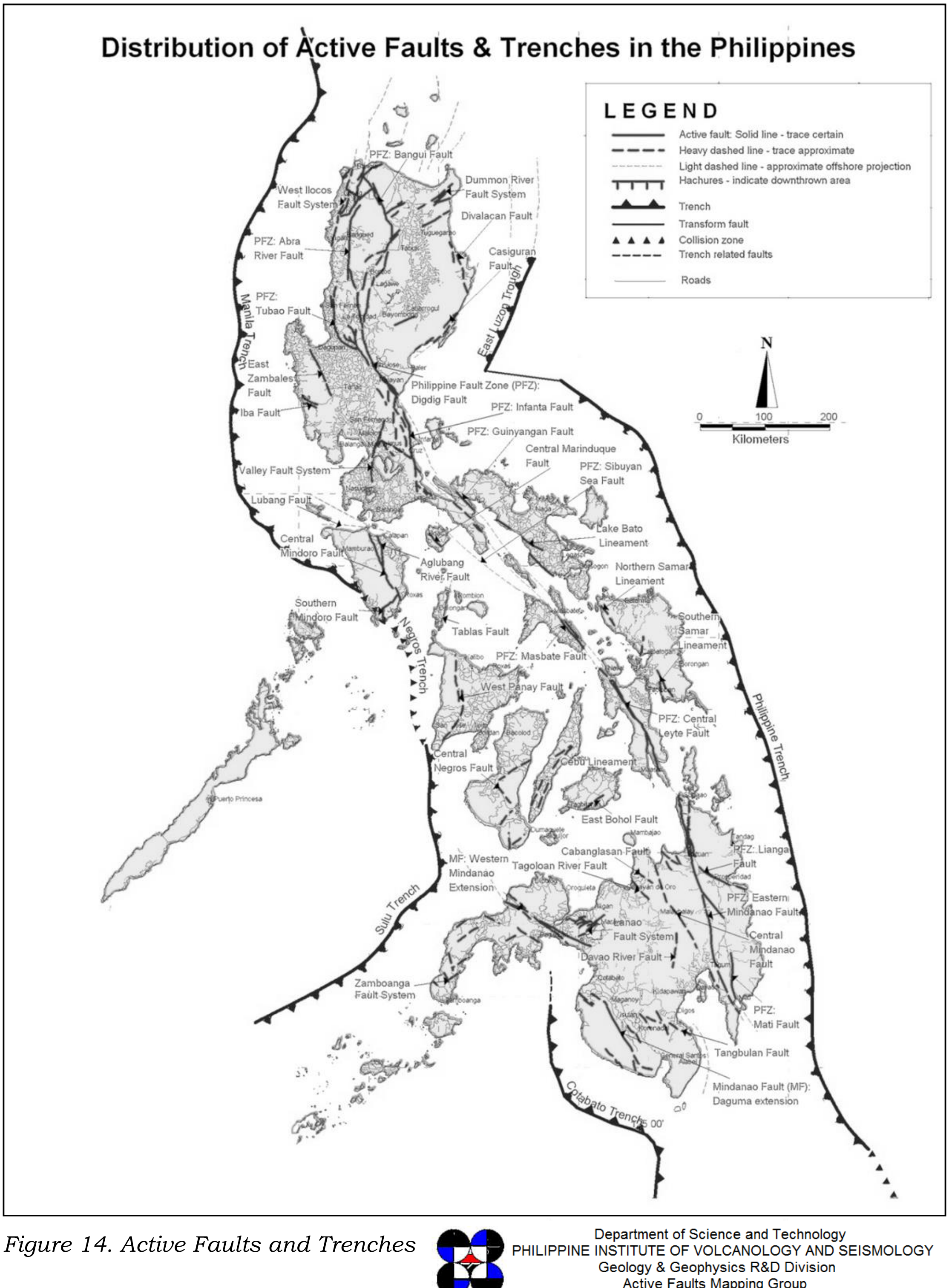


Figure 14. Active Faults and Trenches

Earthquakes and Tsunamis

In March 2011, a powerful earthquake took place in the Pacific Ocean near Japan. Afterward, a tsunami hit Japan. Tens of thousands (please check approximate figures) Twenty thousand people were killed. More than a million houses and buildings were damaged or destroyed.

In December 2004, a strong earthquake occurred in the Indian Ocean near Indonesia. A tsunami soon followed. More than 200,000 people were confirmed dead, many of them in Indonesia, Thailand, India, and Sri Lanka.

In 1976, an earthquake took place in the Moro Gulf in Mindanao. Later on, a tsunami hit nearby coastal areas. Thousands of people were killed. Many more were declared missing.

What is the connection between earthquakes and tsunamis?

Activity 5.
Tsunami!

Objectives:

After performing this activity, you should be able to:

1. explain how tsunamis are generated; and
2. infer why tsunamis do not always occur even when there is an earthquake

Materials Needed:

flat basin or laundry tub (*batya)*
water
rectangular piece of plastic panel or plywood
rock

Procedure:

1. Put water in the container. Place the rock in the water at one end of the container (Figure 15).

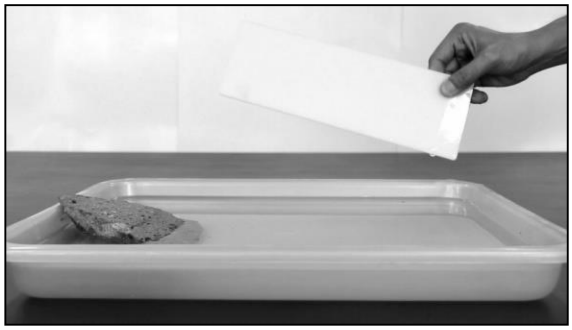


Figure 15. Setup for the tsunami activity

2. At the other end of the container, put the plastic panel flat at the bottom of the container (Figure 16, left).

3. You will need some help: a person to watch the surface of the water, and another to watch the level of water by the rock. Things will happen quickly, so make sure your assistants are alert.

4. Hold the corners of the plastic panel with your thumbs and fingertips. Wait for the water to stop moving. Using only your fingertips, jerk the edge of the plastic board upward (Figure 16, right).

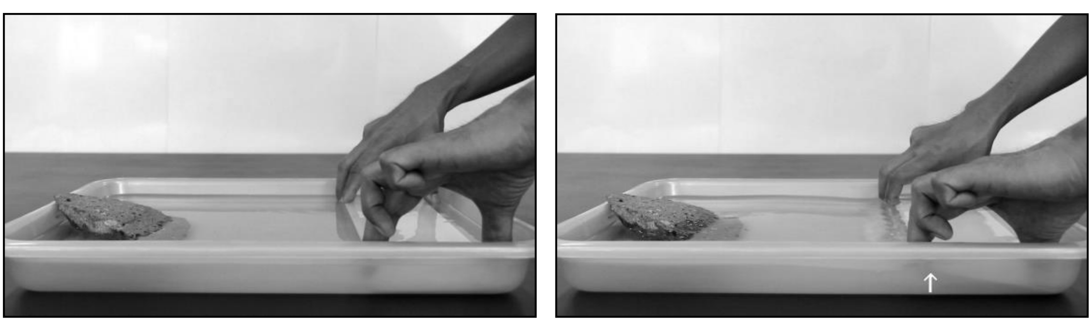


Figure 16. (Left) The plastic panel placed flat at the bottom of the container. (Right) Wait for the water to stop moving, then suddenly jerk the edge of the plastic panel upward (see white arrow).

Q10. What was formed in the water by the sudden push of the plastic panel?

Q11. How was the water level by the rock affected by the wave?

Q12. What does the water represent? How about the rock?

Q13. What does the plastic panel represent?

Faults are found not only on land but also under the sea. When a fault at the bottom of the sea suddenly moves, the water above it can be affected. A sudden push from an underwater fault can produce a wave called a tsunami.

Unlike a wave that is formed by the wind, a tsunami is so much more powerful. Wind waves are just sea-surface waves. In comparison, a tsunami involves the whole depth of the sea, from the seafloor to the surface.

Far from the shore, a tsunami is low, maybe just a meter high. But it travels at the speed of a jet plane. When the tsunami reaches the shore, it slows down but it grows in height.

A tsunami is very destructive because the force of the whole ocean is behind it. This is the reason why whole towns and cities are totally devastated after a tsunami attack.

So, how are earthquakes related to tsunamis? When a fault suddenly moves on land, you get an earthquake. But if a fault suddenly moves in or near a body of water, you may get a tsunami in addition to the earthquake.

Thus, when you are near the sea and you feel a strong earthquake, treat that as a warning signal. Run to the highest place you can find, or if you have a vehicle, evacuate inland.

Not every fault movement beneath the sea will produce a tsunami. Those faults that move in a horizontal direction or sideways will not result in a tsunami. The fault has to move in the vertical sense. In the activity, a sudden upward push triggered the wave.

What's Inside the Earth?

We often think of earthquakes as something harmful and the reason is obvious. But earthquakes help scientists figure out what is inside the Earth. How? As you know by now, when a fault suddenly moves, an earthquake is generated.

The shaking starts from the focus and spreads out. You can get an idea of how this happens by throwing a pebble into a pond. See the ripples that move out in circles? The vibrations from the focus are something like that.

The vibrations are more properly called seismic waves. As seismic waves travel through the body of the Earth, they behave in different ways, depending on what they encounter along way (Figure 17).

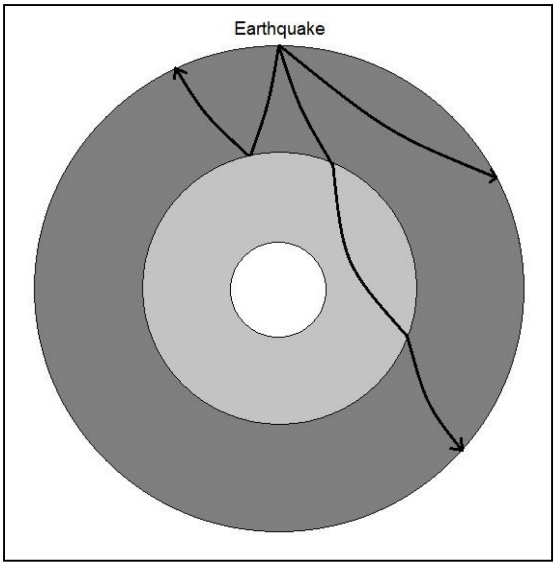


Figure 17. The behavior of seismic waves reveals what the Earth looks like inside.

For example, as seismic waves travel deeper into the crust, they speed up. That means that at depth the rocks are denser. In the upper part of the mantle, the waves slow down. That means the rocks there are partially molten.

As the waves reach the core, one kind of seismic wave (s-waves) disappears. That means that the outer core is liquid. At certain depths, the waves are reflected and refracted (bent). That means the Earth must be layered.

Thus, earthquake waves give us a picture of the Earth's interior, the way an "ultrasound" provides an image of a baby inside the womb. This is why scientists know a bit about the interior of our home planet, even if no one has gone deep into the Earth yet.

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Suggested time allotment: 9 hours

Unit 2
MODULE
2

UNDERSTANDING TYPHOONS

Overview

Every year the Philippines is hit by typhoons. No part of the country is spared. All provinces have been visited by a typhoon at one time or another. In recent years, the Philippines had been overwhelmed by powerful tropical cyclones.

Who could forget the terrible flood brought by Tropical Storm Ondoy in 2009? Or the people swept out to sea during Tropical Storm Sendong in 2011? Or the poor community of New Bataan buried in mud spawned by Typhoon Pablo in 2012?

According to the Philippine Atmospheric, Geophysical, and Astronomical Services Administration (PAGASA), about 20 tropical cyclones enter the Philippine Area of Responsibility each year. We have to be knowledgeable about tropical cyclones if we want to prevent the loss of more lives.

Why is the Philippines prone to typhoons?

What conditions favor the formation of typhoons?

What is a Typhoon?

We all know what a typhoon is. Or more accurately, we know what to expect when a typhoon comes. We get a lot of rain and strong winds. Now, you may not have noticed it but the winds in a typhoon move in a certain direction. They go around a central area. Take a look at Figure 1.

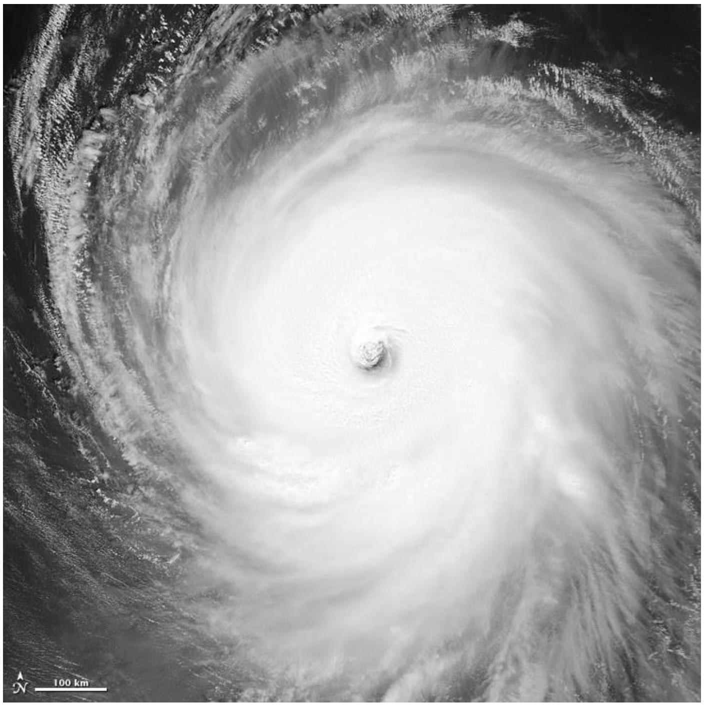


Figure 1. A supertyphoon as seen from high above the Earth; at the center is the "eye" of the supertyphoon. Image by NASA Earth Observatory

The picture shows a supertyphoon as viewed from up above the Earth. A typhoon looks the same, only smaller. See the clouds in a spiral arrangement? They are being blown by winds in a counter-clockwise direction. In a supertyphoon, the wind speed is greater than 200 kilometers per hour (kph).

If the wind speed is less, from 119 to 200 kph, then it is called a typhoon. If the wind speed is between 65 and 118 kph, it is called a tropical storm. And when the wind speed is between 35 to 64 kph, it is a tropical depression.

Tropical depression, *tropical storm*, *typhoon*, and *supertyphoon* are categories of tropical cyclones (Table 1). In simple terms, a tropical cyclone is a system of thunderstorms that are moving around a center. As the winds intensify or weaken, the category is upgraded or downgraded accordingly.

Table 1. Tropical Cyclone Categories

Category	**Maximum Wind Speed kilometers per hour (kph)**
Tropical Depression	64
Tropical Storm	118
Typhoon	200
Supertyphoon	greater than 200

The term *typhoon* is used only in the northwestern part of the Pacific Ocean. In the northeastern part of the Pacific Ocean and in the northern part of the Atlantic Ocean, the equivalent term is *hurricane*. Thus, a hurricane on one side of the Pacific Ocean will be called a typhoon if it crosses into the other side.

In the Philippines, we use the same word for all categories of tropical cyclones. We call it *bagyo* whether it is a tropical depression, a tropical storm or a typhoon.

(At this point, your teacher will give a demonstration.)

Philippine Area of Responsibility

When a weather disturbance enters the Philippine Area of Responsibility (PAR), the weather bureau begins to monitor it. Do you know where the PAR is? Do the following activity to find out.

Activity 1
Plotting the PAR

Objectives:

After performing this activity, you should be able to:

1. read map,
2. given the latitude and longitude of a tropical cyclone, tell if it has entered the Philippine Area of Responsibility, and
3. explain what is meant when a typhoon has entered the Philippine Area of Responsibility.

Materials Needed:

map of the Philippines and vicinity
pencil

Procedure:

1. Plot the following points on the map below (Figure 2).

Points	Latitude, Longitude
a.	5°N, 115°E
b.	15°N, 115°E
c.	21°N, 120°E
d.	25°N, 120°E
e.	25°N, 135°E
f.	5°N, 135°E

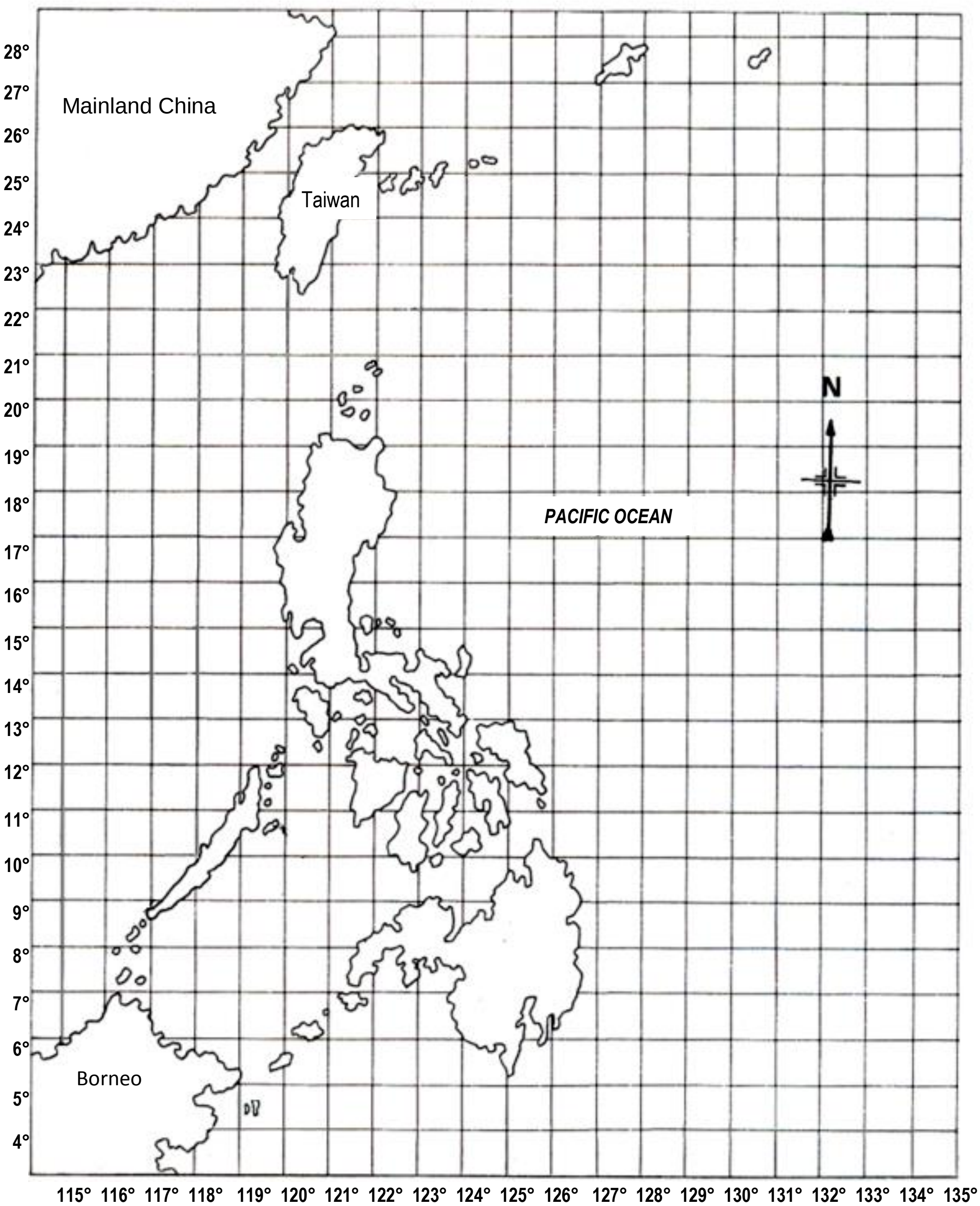


Figure 2. Map of the Philippines and vicinity

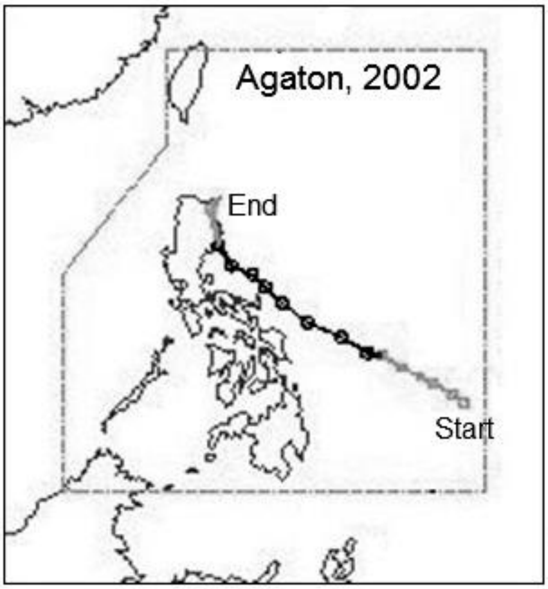
2. Connect the plotted points. The region within is the Philippine Area of Responsibility or PAR. It is the job of PAGASA to monitor all tropical cyclones that enter this area.

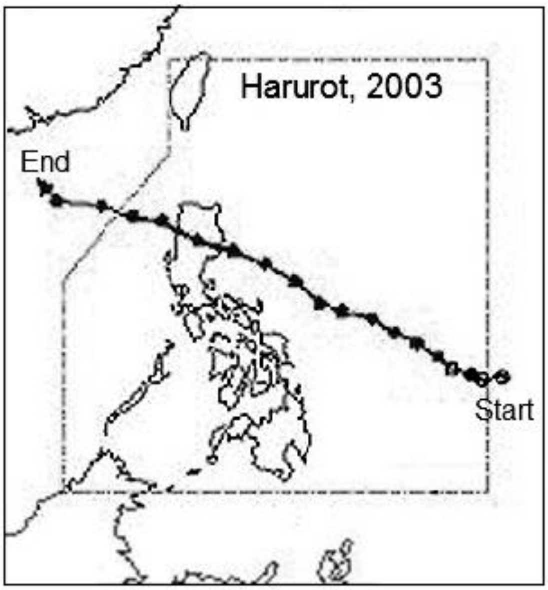
Q1. If a typhoon is located at 15°N, 138°E, is it within the PAR?

Q2. How about if the typhoon is at 19°N, 117°E, is it inside the PAR?

Under What Conditions do Tropical Cyclones Form?

Shown below are the tracks (paths) of four tropical cyclones that entered the PAR in the past years. The tracks were plotted by PAGASA. Study the maps and answer the following questions.





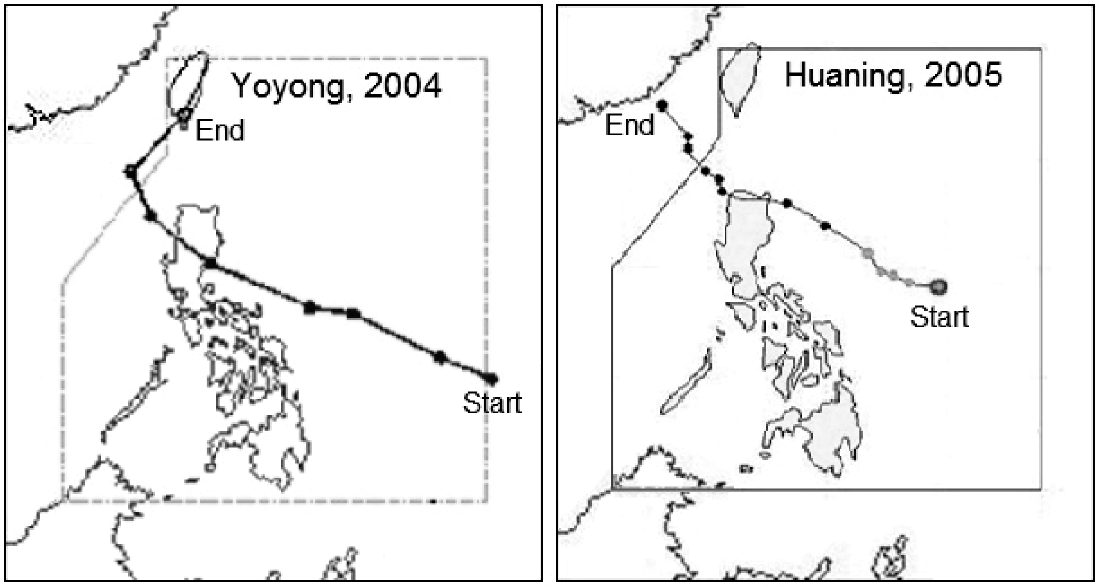


Figure 3. Tracks (paths) of selected tropical cyclones

Where did the tropical cyclones form? On land or in the ocean?

What can you say about the temperature of the bodies of water in the vicinity of the Philippines? Is the water warm or cold?

In what direction did the tropical cyclones move?

Which part of the Philippines was hit by the four tropical cyclones?

In the case of Agaton, Yoyong, and Huaning, where did they die out? Near land or in the middle of the ocean?

Tropical cyclones need water vapor in order to form. Which is a better source of water vapor, landmasses or oceans? The answer is obvious. But not all parts of the ocean can provide water vapor. Where do you think would evaporation be greatest, near the equator or away from the equator?

Thus, tropical cyclones require warm ocean waters to be able to develop. According to scientists, the temperature of ocean water must be 26.5°C or greater. Given this information, do you think typhoons can form in latitudes away from the equator? Why or why not?

From the maps, you can see that tropical cyclones generally move in a northwest direction. The reason is because there are large-scale winds that push the tropical cyclones in that direction. This is similar to the way a whirlpool is carried along by a flowing stream.

As you can observe, all four tropical cyclones struck the northern part of the Philippines. Now you know why the southern part of the Philippines is often untouched by tropical cyclones. Where do you think should a tropical cyclone form so it would hit the Mindanao area?

Three of the tropical cyclones mentioned above weakened and died out near land. Agaton dissipated in Luzon, Yoyong in Taiwan, and Huaning near Mainland China. This means that when tropical cyclones reach land, they die out because they are cut off from the warm ocean waters that keep them going.

Now you know where tropical cyclones start to form, why they form there, and in what direction they generally move. Can you now explain why the Philippines is prone to typhoons?

In the following activity, you will try your hand in tracking a tropical cyclone as it enters and leaves the PAR.

Activity 2
Tracking a tropical cyclone

Objectives:

After performing this activity, you should be able to:

1. determine if your location is in the path of a tropical cyclone, given the latitude and longitude position and

2. explain why PAGASA regularly monitors when a tropical cyclone is within PAR.

Materials Needed:

map with the PAR (from Activity 1)
tracking data
pencil

Procedure:

1. Use the latitude and longitude (lat-long) in the table below to track the location of Sendong. Plot each lat-long pair on the map with the PAR.

Date: 13-19 DEC 2011
Tropical Storm Sendong (International name: Washi)

Month/Day/Time	Latitude (°N)	Longitude (°E)
12/13/06	6.00	145.10
12/13/12	6.40	143.30
12/14/18	6.00	141.70
12/14/00	5.90	140.60
12/14/06	6.20	139.00
12/14/12	6.70	137.70
12/14/18	7.00	136.30
12/15/00	7.20	134.30
12/15/00	7.20	134.30
12/15/06	7.60	132.30
12/15/12	7.70	130.80
12/15/18	7.50	129.10
12/16/00	7.40	128.10
12/16/06	8.00	126.80
12/16/12	8.40	125.50
12/16/18	8.50	123.80
12/17/00	9.10	122.40
12/17/06	9.20	121.50
12/17/12	9.60	120.40
12/17/18	10.20	119.00
12/18/00	10.90	117.60
12/18/06	10.30	115.70
12/18/12	9.90	114.60
12/18/18	9.60	113.90
12/19/00	9.10	112.90
12/19/06	9.70	111.90
12/19/12	10.50	110.70

Tracking data are from
http://weather.unisys.com/hurricane/w_pacific/2011H/index.php

Q3. Where did Sendong form?

Q4. When did Sendong enter the PAR?

Q5. When did Sendong leave the PAR?

Q6. In what direction did Sendong move?

Sendong started out in the Pacific as an area of low pressure. Because it was just a low-pressure area, it was not given a name. Then it intensified into a tropical depression. Again it was not yet given a name because it was still outside the PAR.

When it finally entered the PAR, it had already strengthened into a tropical storm. Since it was within the PAR by then, PAGASA gave it a name—Sendong—from its prepared list. Internationally, the tropical storm was called Washi.

Sendong brought hours of torrential rains to Mindanao. Some places received more than 200 mm of rain. Because of the excess rain, flash floods and landslides took place. Nearly a thousand people were killed, many in the cities of Cagayan de Oro and Iligan. Damage to houses, roads, and bridges reached up to 2 billion pesos.

After the Sendong disaster, who would have thought that another tropical cyclone would again hit Mindanao the following year. Tropical cyclone Pablo (international name, Bopha) was so strong it was categorized as a supertyphoon. Clearly, we need to learn about tropical cyclones in order to survive.

Inside Tropical Cyclones

One thing about tropical cyclones that we should watch out for are the strong winds. Let us now take a peek inside a tropical cyclone and find out in which part would we experience strong winds.

Activity 3
Dissecting a tropical cyclone

Objectives:

After performing this activity, you should be able to:

1. explain what two weather factors tell weathermen that a certain location is at the eye of a tropical cyclone; and

2. put in simple words the statement "calm before the storm."

Materials Needed:

weather data (air pressure and wind speed)

Procedure:

1. Figure 1 consists of two illustrations. The top one shows a tropical cyclone as seen at an angle. White rain bands move around the center or "eye". The bottom illustration shows a cross-section of a tropical cyclone. It is like slicing it in half and looking at it from the side.

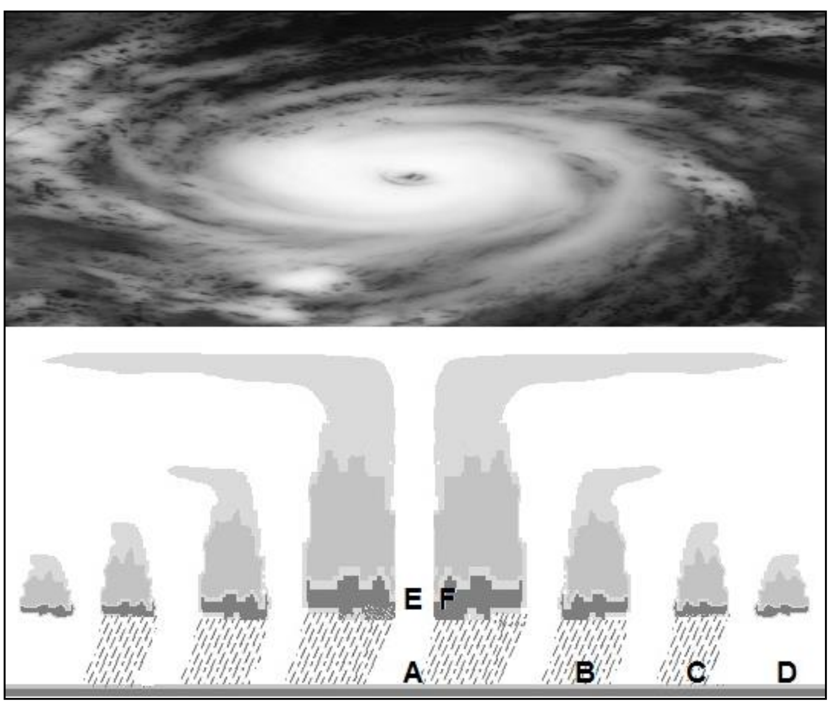


Figure 4. (Top) View of a tropical cyclone at an angle.
(Bottom) Cross-section of a typhoon.

Q7. Location A is within the eye of the tropical cyclone. B, C and D are locations that are more and more distant from the eye. The air pressure at the different locations are:

Location	A	B	C	D
Air pressure* in millibars (mb)	930	960	980	990

*Air pressure refers to the weight of air over a certain area.

Compare the air pressures at A, B, C and D. What do you notice?

Q8. Location E is within the eye of the tropical cyclone. Location F is within the clouds surrounding the eye. The clouds at F make up the eyewall. The wind speed at the two locations are:

Location	E	F
Wind speed (km/hour)	10	200

Compare the wind speed within the eye and at the eyewall. What can you say?

As you have learned from the activity, the lowest air pressure is at the eye of a tropical cyclone. In fact, all tropical cyclones have low air pressure at the center. This is the reason why the air in the surroundings move toward the eye. Recall in Grade 7 that air moves toward low-pressure areas.

You also learned that at the eye of a tropical cyclone, wind speed is low. But in the dense clouds surrounding the eye, at the eyewall itself, the wind speed is great. When newspapers report that a tropical cyclone has sustained winds of 200 km/hour, for instance, they are referring to the winds at the eyewall.

When the eye of a tropical cyclone passes over a certain place, it is the winds at the eyewall that wreak a lot of damage. As it approaches, one side of the eyewall brings strong winds blowing in one direction. Then comes the eye with its somewhat calm weather. As it leaves, the other side of the eyewall brings strong winds again, but this time in the opposite direction.

Are You Prepared?

When a tropical cyclone enters the PAR and it is on its way toward land, warning signals are issued. The following signals are used by PAGASA to warn people about the approaching weather disturbance. Do you know what the signals mean?

PUBLIC STORM WARNING SIGNALS (PSWS)

PSWS # 1

What it means
A tropical cyclone will affect the locality
Winds of 30-60 kph may be expected in at least 36 hours or
irregular rains may be expected within 36 hours

The following may happen
Twigs and branches of small trees are broken
Some banana plants are tilted or downed
Some houses of very light materials partially unroofed
Rice crops suffer significant damage in its flowering stage

What to do
Watch out for big waves
Listen to severe weather bulletin issued by PAGASA

PSWS # 2

What it means

A tropical cyclone will affect the locality

Winds of greater than 60 kph up to 100 kph may be expected in at least 24 hours

The following may happen

Large number of nipa and cogon houses may be partially or totally unroofed

Some old galvanized iron roof may be peeled off

Winds may bring light to moderate damage to exposed communities

Some coconut trees may be tilted while few are broken

Few big trees may be uprooted

Many banana plants may be downed

Rice and corn may be adversely affected

What to do

Avoid riding in small seacraft

Those who travel by sea and air should avoid unnecessary risks

Postpone outdoor activities of children

PSWS # 3

What it means

A tropical cyclone will affect locality

Winds of greater than 100 kph to 185 kph may be expected in at least 18 hours

The following may happen

Many coconut trees broken or destroyed

Almost all banana plants downed and a large number of trees uprooted

Rice and corn crops suffer heavy losses

Majority of all nipa and cogon houses uprooted or destroyed; considerable damage to structures of light to medium construction

Widespread disruption of electrical power and communication services

Moderate to heavy damage experienced in agricultural and indistrial sectors

What to do

Avoid riding in any seacraft
Seek shelter in strong buildings
Evacuate from low-lying areas
Stay away from coasts and river banks

PSWS # 4

What it means

A very intense typhoon will affect locality
very strong winds of more than 185 kph maybe expected in at least 12 hours

The following may happen

Coconut plantation may suffer extensive damage
Many large trees maybe uprooted
Rice and corn plantation may suffer severe losses
Most residential and institutional buildings of mixed construction maybe severely damaged
Electrical power distribution and communication services maybe severely disrupted
Damage to affected communities ca be very heavy

What to do

All travels and outdoor activities should be cancelled
Evacuation to safer shelters should have been completed by now
The locality is very likely to be hit directly by the eye of the typhoon.

To be fully prepared for tropical cyclones, you should also put together an emergency kit which includes the following: drinking water, canned goods, can opener, radio, flashlight, extra batteries, clothes, blanket, and first aid kit. You never know when you will need it. You must learn how to rely on yourself. In times of disaster, it may take a while before help arrives.

References and Links

Tarbuck, E.J., & Lutgens, F.K. (2004). *Earth Science* (10th ed.). First Lok Yang Road, Singapore: Pearson Education (Asia) Pte Ltd.

http://www.pagasa.dost.gov.ph/

http://www.ready.gov/hurricanes

http://www.noaawatch.gov/themes/tropical.php

http://weather.unisys.com/hurricane/w_pacific/2011H/index.php

http://en.wikipedia.org/wiki/Tropical_Storm_Washi

http://people.cas.sc.edu/carbone/modules/mods4car/tropcycl/index.html

Suggested time allotment: 3 to 4 hours

Unit 2
MODULE
3

COMETS, ASTEROIDS, AND METEORS

Overview

Recent advances in space technology have allowed scientists coming from different background such as physics, chemistry, biology, and geology to collaborate on studying Near-Earth Objects (NEO) such as comets and asteroids. With more powerful telescopes and space probes, the study of comets and asteroids provides more clues about the origins of our solar system. Over the past three years, amateur and professional astronomers have discovered several NEOs that came close to Earth, the most recent asteroid being Asteroid 2012 DA14. It made a very close approach to Earth as it orbited the Sun on February 16, 2012 (Philippine Time). In the morning of the same day, an asteroid entered Earth's atmosphere and exploded over Lake Chebarkul in Russia hurting about 1,000 people in the process. These two events triggered superstitions, fears, and doomsday prophecies held by different cultures. But do these things have scientific basis?

Has Earth ever been hit by a comet or an asteroid?
If yes, how have such impacts affected Earth?
How often does a comet or an asteroid hit Earth?

Activity 1
What happens when a comet or an asteroid hits Earth?

Objectives:

After performing this activity, you should be able to:

1. describe how impact craters are formed when a comet or asteroid hits Earth based on a simulation; and

2. present observations on simulating a comet or asteroid impact using drawings.

Materials Needed:

1 rectangular container (aluminum tray or plastic)
1 pebble (1-4 cm in diameter)
colored flour/colored starch
pencil

Procedure:

1. Fill the rectangular tray with colored flour about 3-4 centimeters deep.

2. Place the tray on top of a table (or armrest of a chair).

3. Throw a pebble to hit the flour in the tray. Do this about four times, hitting different parts of the flour in the tray.

4. In the space below, draw the shape of the “craters” made by the pebble on the colored flour as:

   a. viewed from the top.

   b. viewed from the side

5. Compare the shape of the pebble’s “crater” with the shape of the impact crater photo shown below.

Meteor Crater near Winslow, Arizona, USA
(Permission obtained from the Center for Science Education,
UC Berkeley Space Sciences Laboratory)

Q1. What do you notice about the shape of your pebble’s crater and the shape of the impact crater shown in the photo?

Q2. What do you think happened to the plants and animals living in the area where the comet or asteroid crashed?

Comets and asteroids are referred to by astronomers as Near-Earth Objects (NEO). Comets are icy bodies or objects while asteroids are rocky fragments. They are remnants from the formation of our solar system 4.6 billion years ago. The table below summarizes the similarities and differences between comets and asteroids.

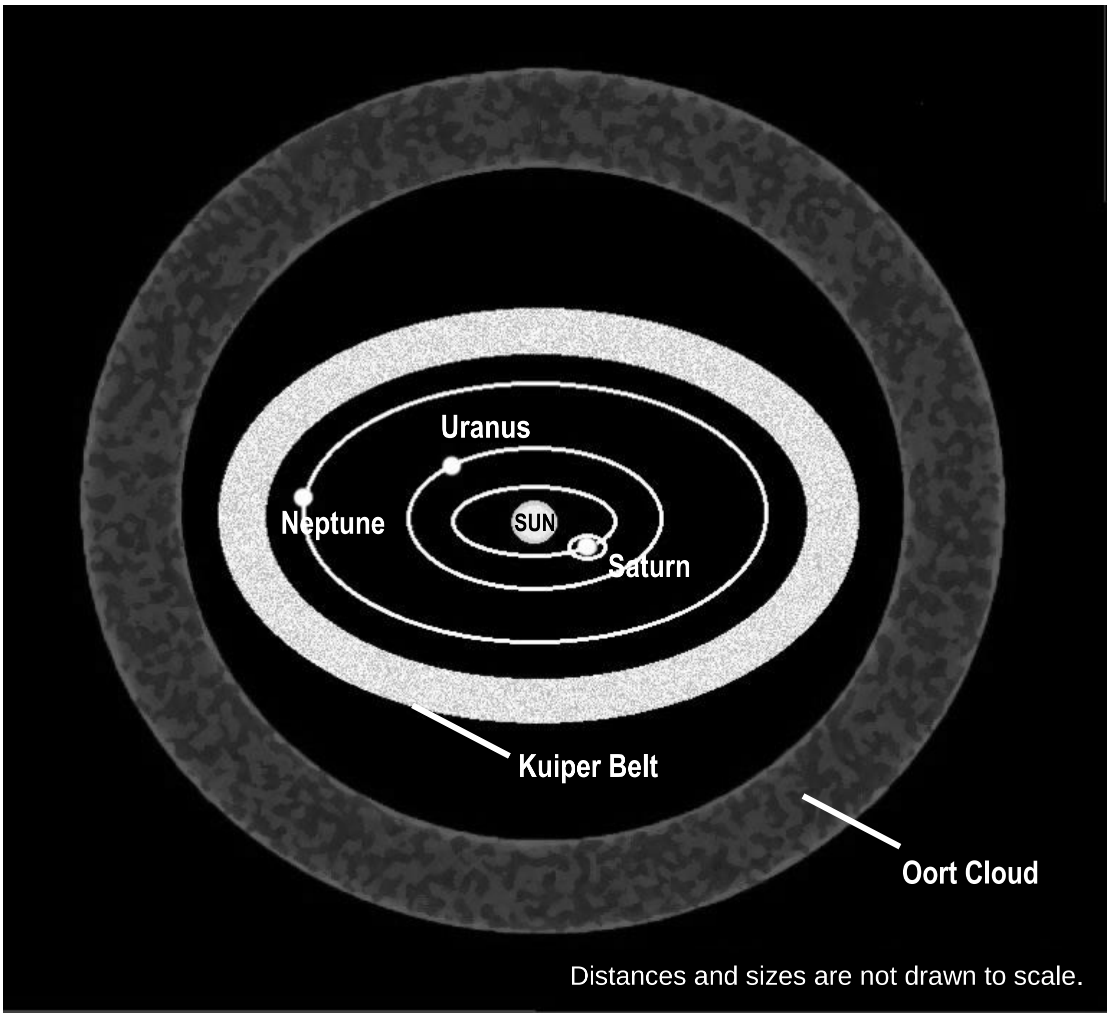
Table 1. Comparison of some characteristics of comets and asteroids

Characteristic	Comet	Asteroid
Origin	Kuiper Belt and Oort Cloud	Main Asteroid Belt
Shape	Varied/Irregular	Varied/Irregular
Size range of diameter (kilometer)	1-10 (nucleus only)	1 – 100++
Chemical composition	Ice (frozen water); frozen gases (ammonia, methane, and carbon dioxide); other organic compounds (Carbon-containing compounds)	Silicates (olivine and pyroxene), iron, nickel
Orbit	Highly elliptical	More rounded
Orbital period (years)	75 to 100,000++	1-100

Q3. Which is most likely to make a more frequent "visitor" of Earth: a comet or an asteroid? Why do you think so?

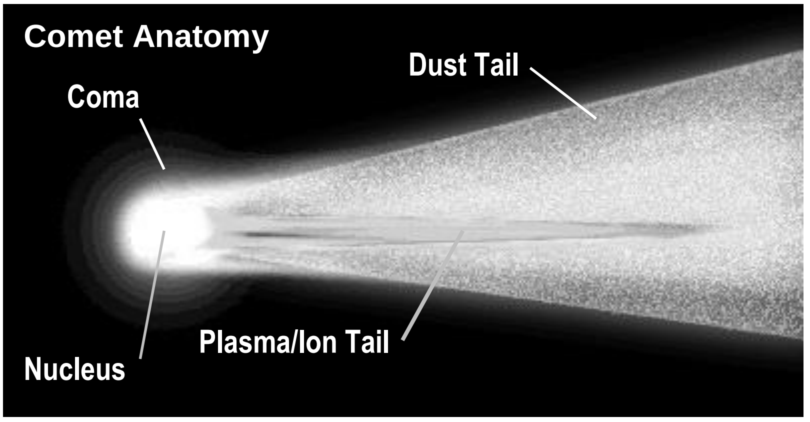
As you can see in the table, comets and asteroids have irregular shapes and varied sizes. They both reflect light from the Sun in varying amounts depending on the size and composition. The presence of more silicates allows a comet or asteroid to reflect light. Silicates are minerals that contain the elements silicon, oxygen, and at least one metal. If an asteroid has smaller amounts of silicates relative to its other components, it would be more difficult to see it even with a telescope because only a small area of the asteroid can reflect light thus it may appear smaller than what it really is when viewed.

Comets and asteroids both orbit the Sun and move relatively slow when viewed from Earth. This means, you can see a comet for up to a year in the night sky (or even during the morning if the comet is bright enough). The major difference is their origin or where they came from in space. Comets usually come from the Oort Cloud which is beyond our Solar System, and a few from Kuiper Belt which is just beyond Neptune's orbit. Long-period comets come from the Oort Cloud, while short-period comets come from the Kuiper Belt. Comet Halley, the most famous comet of the 20th century is the only known short-period comet. It takes 75-79 years for Comet Halley to orbit the Sun. We see it in the sky every time it makes its nearest approach to the Sun. All other comets that have been identified are classified as long-period comets and takes 200 to hundred millions of years to complete their orbit around the Sun. Asteroids, on the other hand, originate from the Main Asteroid Belt between Mars and Jupiter. This belt is theorized by scientists to be remnants of a planet that did not completely form.



The orbit of an asteroid is more rounded and less elliptical than the orbit of a comet. In February 2013, Asteroid 2012 DA14 made a very close approach to Earth as it orbited the Sun. Distance in space is measured in light years and this Asteroid was just 0.4 light year away from Earth, the closest that any asteroid has ever been to Earth. In December 2012, during the midst of the doomsday prophecies, Asteroid Toutatis also made a near approach to Earth but not as close as Asteroid 2012 DA14.

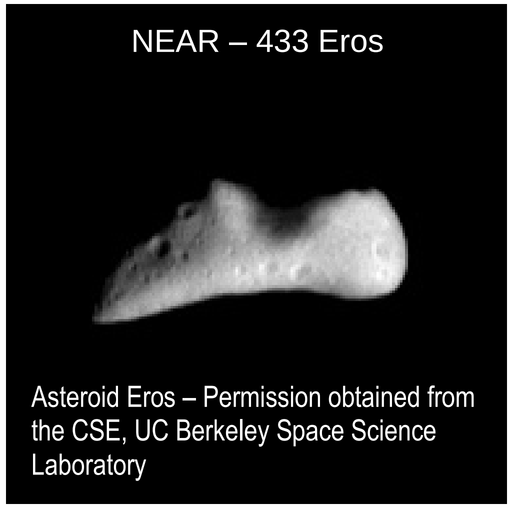
Another difference between a comet and an asteroid is their chemical composition. Comets are icy objects while asteroids are rocky fragments. Sometimes, comets may contain other elements like sodium or argon, which is specific to a comet. Through further studies, scientists learned that Comet Hale-Bopp contained argon which was believed to explain the very bright appearance of the comet in 1997. Scientists also discovered a faint sodium tail, a third type of comet tail to add to the well-known dust and plasma (or ion) tails. On the other hand, an asteroid is mostly composed of rock (silicates) and metals (iron and nickel being the usual metals).



Permission obtained from the Center for Science Education (CSE), UC Berkeley Space Sciences Laboratory

The composition of a comet is important in helping scientists understand how Earth has liquid water, which in turn made the planet livable. During Earth's formation, scientists theorized that the planet must have been too hot to have liquid water on its surface. By studying comets' orbits and the chemical composition of materials found in impact craters found all over Earth, soil and ice samples collected from drilling down Earth's crust and marine layers, scientists theorized that the early impact of comets on Earth brought liquid water to the planet.

The chemical composition of an asteroid is important in providing clues for scientists to discover more about the chemical composition of Earth and the other planets in the Solar System, as well as how life on Earth was affected by impacts in the past. It is the scientists' belief that Earth, other planets, and asteroids are essentially similar in composition. In fact, asteroids are also called minor planets or planetoids. Asteroids are mostly composed of metals like iron and nickel; the same metals that are theorized to make up Earth's core.



NEAR – 433 Eros

Asteroid Eros – Permission obtained from the CSE, UC Berkeley Space Science Laboratory

The discovery of high contents of iridium in oceanic sedimentary layers in different parts of the world such as Italy, Denmark, and New Zealand during the late 1970s led geologists, Luis and Walter Alvarez to propose the **Alvarez Hypothesis** in 1980. Iridium is a metal belonging to the Platinum family. It is very rarely found in Earth's crust, but more abundant in the mantle and core. It is also abundant in our solar system. They proposed that an asteroid with approximately 10 kilometers in diameter made impact with Earth 65 million years ago. They thought that the impact caused materials to be thrown up in air, thus blocking sunlight, and bringing about a period of winter long enough to cause a mass extinction of plants and animals, including the dinosaurs. Further, this event ended the Cretaceous Period and ushered in the Tertiary Period.

> If you want to learn more about the Impact Theory, visit:
> http://hoopermuseum.earthsci.carleton.ca/saleem/meteor.htm

Comets and asteroids orbit the Sun, but it is theorized by scientists that other planets in our solar system can influence and alter the orbital path of these NEOs, thus they come crashing towards Earth. By studying the orbits of known NEOs, scientists have calculated the orbital periods that indicate when these objects will make their closest approach to Earth as they orbit Sun, or predict the likelihood of a collision with Earth. While asteroids and comets have collided with Earth in the past, the frequency is very much longer than a human lifetime, so there is no need to worry.

Activity 2
Meteoroid, meteor, and meteorite: How are they related?

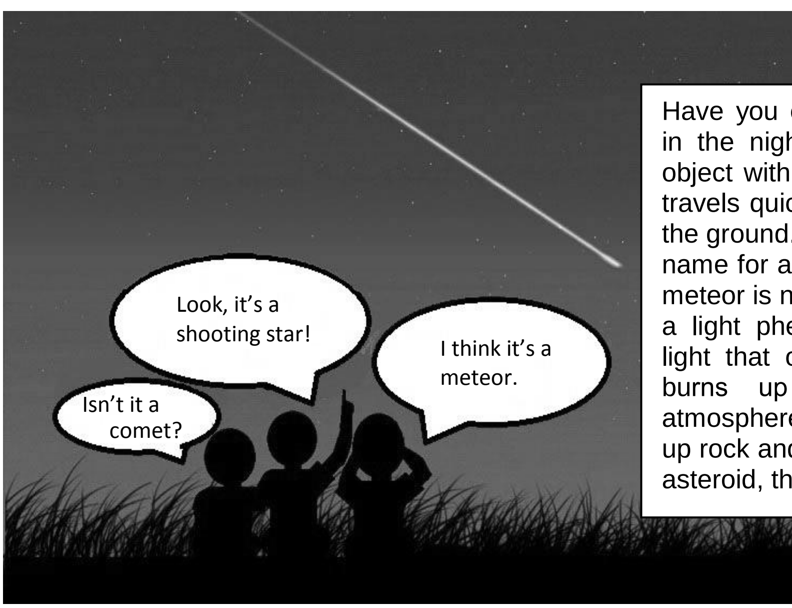
Objectives:

After performing this activity, you should be able to:

1. describe the changes that happens to a fragment from a comet or asteroid as it enters Earth's atmosphere;
2. represent the relationship between a meteoroid, meteor, and meteorite using a diagram; and
3. explain how meteoroid, meteor, and meteorite are related.

Procedure:

Read the selection below and answer the questions as you go along



Have you ever seen a shooting star in the night sky? It appears as an object with a tail just like a comet. It travels quickly and appears to fall on the ground. A shooting star is another name for a meteor. But the truth is: a meteor is not a star at all. A meteor is a light phenomenon or a streak of light that occurs when a meteoroid burns up as it enters Earth's atmosphere. A meteoroid is a broken up rock and dust from either a comet, asteroid, the Moon, or from Mars.

Q1. What is a meteor?

Q2. What is a meteoroid?

Q3. What celestial (space) objects can a meteoroid come from?

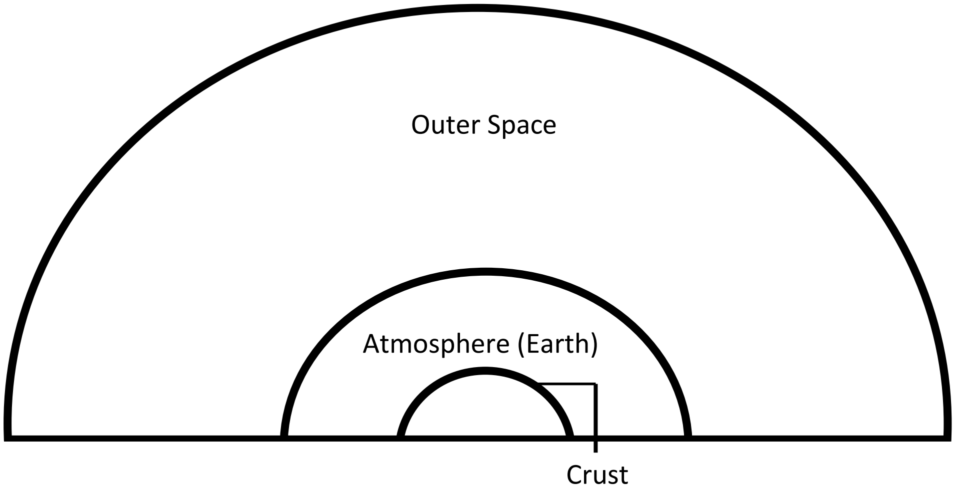
A meteoroid can be as small as a grain of sand or as big as a boulder. When it enters Earth's atmosphere, the air in front of the meteoroid heats up, causing materials to burn up. From Earth, these glowing materials appear as a streak of light or a fast-moving bright object that appears to have a tail just like a comet. What differentiates the two when we see them in the sky is that a comet moves slowly and appears in the sky for a longer time. A meteor moves swiftly and seems to fall on the ground. It "shoots" from a point in the sky, making people think that it is a shooting or falling star. Also, a comet is difficult to see with the unaided eye because it is farther from Earth compared to a meteoroid entering Earth's atmosphere. Sometimes, a comet can be bright enough to be seen by the unaided eye, but this is rare, such as in the case of Comet Hale-Bopp.

Q4. What causes a meteor?

Q5. How can you differentiate a meteor from a comet when viewed from Earth?

A **meteoroid** usually all burns up when it enters Earth's atmosphere. But when a fragment from the meteoroid survives and makes it to the ground, this space rock fragment is now called a **meteorite**. So if you heard from the news on radio or television or read from newspapers about a meteorite exploding over Russia in February 2013, their use of the word meteorite is inaccurate. Instead, a meteoroid exploded over Russia. The space rock fragments they collected on the ground are the meteorites.

Q6. Show where a meteoroid, meteor, and meteorite are most likely to be found in the diagram below. Use the following symbols for each: ■ meteor; ● meteoroid; and ◆ meteorite.



Note: Dimensions are not drawn to scale.

Q7. How are a meteor, meteoroid, and meteorite related?

Earlier, we mentioned that a meteoroid can come from comets. Comets orbit the Sun and leave fragments along their orbit as they continue their journey around the Sun. These fragments continue to orbit the Sun just like their parent comets. When Earth orbits the Sun and passes through the orbit of a comet where these comet fragments are found, we observe many streaks of light from Earth which is called a **meteor shower**. During a meteor shower, meteors seem to originate from only one point in the sky because the meteoroids are traveling in parallel paths with the same velocity. The meteor shower is named after the constellation where they seem to originate from, but this does not mean that the meteoroids come from the associated constellation. Remember: **a meteor and a meteor shower are light phenomena; they are not stars.**

The number of meteors that can be seen during a meteor shower vary. It starts with the appearance of a few meteors per hour, increasing in frequency until it reaches its peak of 1-2 meteors per minute, and then declines. The table below shows some of the more famous annual meteor showers and the month when they reach their peak. The dates in the peak month vary and astronomers make forecasts of the peak days (usually lasting for three days) every year.

Table 2. Some Examples of Famous Annual Meteor Showers

Month	**Source of meteoroid**	**Name of the Meteor Shower**	**Constellation (where the meteor shower seem to come from)**
August	Comet Swift-Tuttle	Perseid	Perseus
October	Comet 21P/ Giacobini-Zinner	Draconid	Draco
October	Comet Halley	Orionid	Orion
November	Comet Tempel-Tuttle	Leonid	Leo
November	Comet Encke	Taurid	Taurus
December	Asteroid 3200 Phaethon	Geminid	Gemini
Note: There is no need to memorize the names of these comets and asteroids.			

Usually, the meteoroids that cause meteor showers come from comets, but they may also come from an asteroid like in the case of the Geminids. Earth passes through Asteroid3200 Phaethon's orbit where some fragments from the asteroid are found. Once these fragments enter Earth's atmosphere, they burn up. Meteoroids from comets appear fuzzy because of the ice particles while those from asteroids are clearer and distinct because they do not have these ice particles.

Q8. What is a meteor shower?

Q9. Why does a meteor shower occur?

Q10. Why does it seem that meteors during a meteor shower appear to come from only one point in the sky?

From the reading activity, you learned how a meteoroid, meteor, and meteorite are related. It is a visual treat to see a meteor at night; more so if you get to see a meteor shower. How much and how well you can see meteors in the sky depend on several factors: air pollution; light pollution; the time of day; weather conditions; size of the meteoroids; source of the meteoroid (comet versus asteroid);

and the chemical composition of the meteoroid itself. It is harder to see them in cities where there are many artificial light sources and where the air tend to be more polluted causing a smog or haze to block the light coming from meteors). Meteor showers are easier to observe at night especially between midnight up to around an hour before dawn.

Meteorites are of importance to scientists in studying the occurrence of different elements and compounds on Earth. This information is in turn important in studying our mineral resources which is an important industry in any country. Generally, there are **three types: stony, stony-iron, and iron meteorites**. In the Philippines, there are only five meteorites that have been accepted internationally. The table below enumerates these meteorites.

Table 3. Five Meteorites Found in the Philippines (Internationally Validated)

Meteorite	**Year of Discovery**	**Place Discovered**	**Type**	**Chemical Composition**
Pampanga	1859	Pampanga	Stony	Iron-Nickel (7-11%); Ferrous sulfide (FeS); Magnesium iron silicate (olivine $(Mg,Fe)_2SiO_4$)); Calcium-Aluminum intrusions (Ca-Al); pyroxene or $XY(Si,Al)_2O_6$ (X can be calcium, sodium, iron^{+2} and magnesium and more rarely zinc, manganese and lithium; Y represents smaller-sized ions like chromium, aluminium, iron^{+3}, magnesium, manganese, scandium, titanium, vanadium and iron^{+2}).
Paitan	1910	Paitan, Ilocos	Stony	Iron; Magnesium iron silicate (olivine $(Mg,Fe)_2SiO_4$)); pyroxene
Calivo	1916	Western Visayas	Stony	Not yet determined
Pantar	1938	Central Mindanao	Stony meteorite	Iron; Magnesium iron silicate (olivine $(Mg,Fe)_2SiO_4$)); pyroxene
Bondoc	1956	Southern Tagalog	Stony-iron	Metallic iron-nickel; silicates (olivine and pyroxene)

The elements and compounds enumerated in the table show that meteorites are very rich in mineral resources. A comet or asteroid does not only bring with it minerals from space but also causes the Earth rocks found in these areas to change in chemical composition. The presence of these meteorites and impact craters hold much potential for the mining industry aside from being objects of scientific scrutiny.

TO LEARN MORE ABOUT METEOR, METEOROID, AND METEORITE, VISIT THESE LINKS:

- http://www.pibburns.com/catastro/meteors.htm
- http://hubblesite.org/reference_desk/faq/answer.php.id=22&cat=solarsystem
- http://cse.ssl.berkeley.edu/segwayed/lessons/cometstale/frame_place.html

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Activity 3
Do superstitions about comets, asteroids, and meteors have scientific basis?

Objectives:

After performing this activity, you should be able to:

1. provide sound, scientific evidence to support one's stand about superstitions on comets, asteroids, and meteors; and
2. formulate doable actions to address superstitions on comets, asteroids, and meteors.

Materials Needed:

pen
paper (for taking notes)

Procedure

1. Research about superstitions related to comet and asteroid in the library, internet, and by interviewing your parents or elderly neighbors.
2. Choose at least three superstitions (one from the Philippines, and the rest from other countries).
3. Discuss each superstition with the group to answer the question: Do superstitions about comets and asteroids have scientific basis? Why or why not?
4. List down as many scientific evidence to support the group's answer to the question. The group may go back to the library to research for more evidence in books or online resources.
5. Propose doable actions that the group can do to promote a more scientific attitude towards comets, asteroids, and meteors to their fellow students or to family members.

Group _______________ Date ______________________
Members ____

Do superstitions about comets and asteroids have scientific basis? Why?

Answer:
____
____

Scientific facts/evidence to support the group's answer:

Proposed actions to promote a more scientific understanding of comets, asteroids, and meteors:

Celestial visitors like comets, asteroids, and meteors have always captured the imagination of ancient civilizations. They have been thought of as bad omens or signs of great change or challenge such as ushering disasters and wars. But with new scientific processes and tools, as well as greater access to scientific information, these celestial visitors have gained the appreciation and interest of many people, scientists and non-scientists included, all over the world.

To learn more about the origins of superstitions about comets, asteroids, and meteors, visit: http://cse.ssl.berkeley.edu/segwayed/lessons/cometstale/frame_history.html

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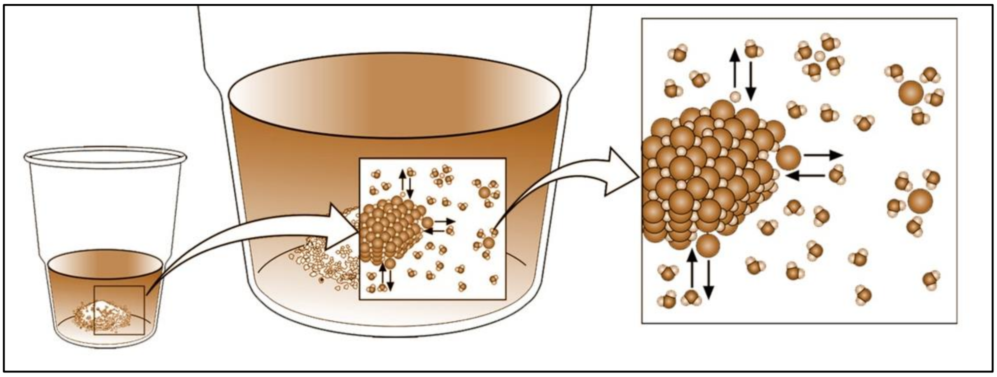
UNIT 3
Matter



Suggested time allotment: 12 hours

Unit 3
MODULE
1

THE PARTICLE NATURE OF MATTER

Overview

In Grade 7, you recognized that there is a wide variety of materials and these materials combine in many ways and through different processes. With this diversity of materials, you learned that chemists came up with several ways of classifying them—heterogeneous and homogeneous mixtures, elements and compounds, metals and non-metals, and acids and bases. By engaging in simple scientific investigations, you were able to recognize some properties of solutions, which are classified as homogeneous mixtures. You also studied the properties of common elements, compounds, metals and non-metals, as well as solutions of acids and bases.

The approach in this module is for you to observe, experience and represent through drawings, illustrations, or cartoons the different phenomena that will help you gradually understand what the particle nature of matter is all about. In Activity 1, you will use what you have learned in previous grade levels to differentiate matter from those which are not matter. In the second and third activities, you will look at situations that support the idea that matter is made up of tiny particles, which you cannot observe with your unaided eyes. This fundamental idea will enable you to learn that the properties of matter are a result of the arrangement of particles it is made of. In Activities 4 to 6, you will use and apply the particle model of matter to explain the following changes in matter: liquid to gas, gas to liquid, solid to liquid, and liquid to solid. At the end of Module 1, you will be able to answer the following key questions.

What is matter made of?
How does the particle model of matter explain some observed properties and changes in matter?

Activity 1
Which is matter, which is not?

Objectives:

After performing this activity, you should be able to:

1. describe common properties of matter;
2. distinguish properties of matter from those of non-matter; and
3. demonstrate the skill of measuring mass.

Materials Needed:

1 teaspoon sugar in a plastic cup or small beaker
½ cup tapwater
1 piece, stone or small rock
1 piece, ball (basketball, volleyball, or small beach ball)
3 pieces of leaves (from any plant or tree)
5 small wide-mouthed bottles or cups or 150-mL or 200-mL beakers
1 platform balance or weighing scale
1 small air pump

Procedure:

1. Among the materials displayed in front of you, which do you think is classified as matter? Put a check (✓) under the appropriate column in Table 1. You may make a table similar to the one below. With your group mates, discuss the reason to explain your answer for each sample. Write your answer in the last column.

Table 1.Identifying which is matter

Sample	Is the sample matter?			Reason for your answer
	Yes	No	Not sure	
sugar granules				
water				
stone				
air inside ball				
leaves				
smoke				
heat				
light				

2. If your group cannot agree on a common answer, you may put a check mark under “not sure” and write all the reasons given by the members of your group.

Q1. What similarities do you observe among the firstfive given samples? Write these common characteristics.

Q2. Does each sample have a measurable mass? Prove your answer by demonstrating how you measure the mass of each sample. Record the mass you got for each sample.

Q3. Do you think that each sample occupies space? Write the reason(s) for your answer.

Q4. How about smoke? Does it have mass? Does it occupy space? Explain your answer.

Q5. Do you think that heat and light have mass? Do they occupy space? Explain your answer.

Based on your observations, you have just described some characteristics of matter. As you were observing each sample of matter in Activity 1, you were focusing on particular characteristics. These characteristics that describe a sample of matter are called **properties**. Matter can have different properties. You measured the mass of each sample of matter using a balance or a weighing scale. The **mass** of an object is a measure of the amount of matter the object has. You observed that the mass of each sample of matter in Activity 1 is different from the mass of the other samples. You also found out that each sample of matter occupies space. The measure of the space occupied by an object is called **volume**. All matter have mass and volume. There are other properties of matter such as hardness, texture, color, flexibility, malleability, and electrical conductivity which vary from one sample to another.

Recall that in Grade 7, you studied other properties of matter. You performed activities to find out some common properties of solutions. You investigated how fast sugar and salt dissolve in water. You compared the boiling point of a substance (distilled water) with that of a mixture (sea water).

Now that you can correctly describe matter based on the properties you have observed, it is important that you know what matter is made of. What makes up matter? If you hammer the stone you used in Activity 1 into much smaller pieces, what would you get? If you turn the sugar into very fine powder, what would result? Ice, liquid water, and steam are all the same substance, which is water, yet you can observe that they look different from each other? How can this be explained? These questions can be answered in the next activity.

Activity 2
What is matter made of?

Objectives:

After performing this activity, you should be able to:

1. infer from given situations or observable events what matter is made of; and
2. explain how these observed situations or events give evidence that matter is made up of tiny particles.

Materials Needed:

½ cup refined sugar
1 cup distilled or clean tap water
1 piece, 100-mL graduated cylinder
1 measuring cup (1 cup capacity)
1 piece transparent bottle (can hold one cup of water) or 250-mL beaker
food coloring (blue, green, or red)
1 dropper
1 stirrer (plastic coffee stirrer or stirring rod)

Procedure:

TAKE CARE! Clean all glassware & containers very well since you will be tasting the mixture.

1. Using a clean and dry graduated cylinder, pour sugar until the 20 mL mark of the graduated cylinder.

2. Transfer the measured sugar into a 250-mL beaker or transparent bottle.

3. Measure 50 mL of distilled or clean tap water using graduated cylinder.

4. Add the 50 mL water to the sugar and mix thoroughly until all the sugar dissolves. Taste the resulting solution. (CAUTION: Do not taste anything in the laboratory unless specifically told to do so by your teacher)

Q1. What is the taste of the resulting mixture?

Q2. Think about sugar and water as made up of tiny particles. With your groupmates, discuss and give your reason(s) for the observations you made in Q1. You may draw illustrations to further explain your reason(s).

5. Transfer the sugar mixture into a graduated cylinder.

Q3. What is the volume of the sugar and water mixture?

Q4. Is the volume of the resulting sugar mixture equal, more than or less than the sum (20 mL sugar + 50 mL water) of the volumes of the unmixed sugar and water?

Q5. Think about sugar and water as made up of tiny particles. With your groupmates, discuss and give your reason(s) for the observations you made in Q3. You may draw illustrations to further explain your reason(s).

6. Pour one cup of tap water into a transparent glass bottle.

7. Add one small drop of food coloring slowly along the side of the transparent bottle.

Q6. Describe what you observe after adding the food coloring.

8. Set aside the bottle with food coloring in a locker or corner of your room without disturbing the setup. Describe the appearance of the contents of the bottle after one day. Compare it with the appearance when you left the bottle the previous day.

Q7. What happens to the food coloring dropped in the bottle containing water? Write all your observations in your notebook.

Q8. Think about food coloring and water as made up of particles. With your groupmates, discuss and give your reason(s) for the observations you made in Q6. You may draw illustrations to further explain your reason(s).

Studying about what matter is made of involves dealing with very small "particles" beyond what your eyes can see. In fact, the ancient Greek philosophers proposed ideas about what matter was made of. Almost 2,500 years ago, Leucippus and his disciple, Democritus believed that nature consisted of two things, "atoms and the void that surrounds them" (Knieram, 1995-2013). They believed that "atoms are physically, but not geometrically, indivisible." For Democritus, atoms are indestructible and completely full, so there is no empty space. Both Leucippus and Democritus had the idea that there are many different kinds of atoms and each of them had specific shape and size and that all atoms move randomly around in space. However they did not give an explanation for the motion of atoms. (Knieram, 1995-2013).

Democritus believed that any piece of matter can be divided and subdivided into very small particles but that this process ended at some point when a piece is reached that could not be further divided. He called this particle, *atomos*, a Greek word which means indivisible particle. Democritus' ideas about the atom were later challenged by other Greek philosophers, most strongly by Aristotle.

The idea of the atom was not further explored until a little over two centuries ago when John Dalton presented concrete evidence that all matter is made of very small particles called atoms. An **atom** is the smallest particle of an element that has all the properties of the element. Today, we know that although atoms are very small, they are not indivisible as Democritus thought, rather they consist of still smaller particles, Democritus was right in one aspect of his belief, that is, atoms are the smallest particles of which substances are made. In Grade 7, you learned about elements. Atoms of most elements have the ability to combine with other atoms. Different elements have different properties because the combining atoms are different and the way the atoms are joined together are different. In Module 2 of this quarter, you will learn about how the model of the atom evolved until the present time. You will also learn that an atom is made of even smaller parts.

A **molecule** is a particle consisting of two or more atoms combined together in a specific arrangement. It is an electrically neutral particle. It is the smallest particle of an element or compound that can exist independently. For example, a molecule of water consists of an oxygen atom combined with two hydrogen atoms. Atoms of the same element can also combine to form a molecule. For example, oxygen in the air consist of oxygen molecules which are made up of two oxygen atoms.

Atoms are too small to observe. These particles cannot be seen under the high-powered light microscopes used in school laboratories. The size of an atom is measured in angstroms. One **angstrom** is a unit of length equal to one ten millionth of a millimetre.

The best light microscope can magnify an image only about 1,500 times. Electron microscopes create a highly magnified image of up to 1 million times. The scanning tunneling microscope (STM) allows scientists to view and scan the surface of very small particles like atoms. It can magnify an image 10 million times. The STM creates a profile of the surface of an atom and then a computer-generated model or contour map is produced. So, only a model of the surface of an atom is generated by a computer when a scanning tunnelling microscope is used. The picture of atoms generated is unlike the picture we take with our cameras.

In Activity 2, when you mixed sugar and water and tasted the resulting solution, it tasted sweet because sugar is still present, though you cannot see the sugar anymore. The volume of the mixture is less than the sum of the volumes of the unmixed sugar and water. Why is this so? The water is made of tiny particles, molecules, with spaces between them. Sugar is also made up of molecules bigger than the molecules of water. The water molecules could fit in the spaces between the sugar molecules or vise versa.

A good analogy to consider related to matter being composed of tiny particles is the pointillist style of painting. The images in a pointillist painting appear continuous but if one looks closely, the images are actually made of small dots. Pointillism is a method of painting using dots to come up with various effects. The dots are placed singly, in rows, or randomly. These dots can also be in groups or they can be overlapping. They can be either uniform or varied in size in the same painting. Matter is similarly assembled, with atoms of different elements combining in various ways to give a tremendous variety of substances.

Figure 1(a). Continuous image of a pointillist painting

Figure 1(b). Blown-up image of a portion of Figure 1a. Dots are more conspicuous.

In Figure 1(a), the image of Dolores F. Hernandez, founding Director of the Science Education Center, now University of the Philippines National Institute for Science and Mathematics Education Development was done through pointillist painting. The image appears continuous. In Figure 1(b), a portion of the painting (boxed in Figure 1a) is blown up to show that the continuous image actually consists of dots. The lightness and darkness of the pigments give volume to the image in order to show smoothness. Similarly, matter, which appears to be continuous like the image in Figure 1(a) is made up of very small particles that cannot be seen with the unaided eye.

In the next activity, you will observe a situation to infer that particles of matter are moving and there are spaces between them.

Activity 3
Are the particles of matter moving? What is between them?

Objectives:

After performing this activity, you should be able to:

1. infer from observations that particles of matter move; and
2. represent through a drawing/illustration what is between particles of matter.

Materials Needed:

2 cups tap water
1 piece, 30 mL plastic syringe (without the needle)
1 piece, wide-mouthed transparent bottle (200 or 250 mL capacity)
1 piece, narrow-mouthed transparent bottle (100 mL capacity)
1 plastic or glass dinner plate
½ cup rock salt (not iodized salt) **or** ½ cup sand
food coloring (blue, green, or red)

Procedure:

1. Pull the plunger of the syringe until it reaches the 30 mL mark of the syringe.

2. Press your thumb on the tip of the plunger and use your other thumb to push the plunger once.

Q1. Can you push the plunger all the way through the syringe while your thumb presses on the tip of the plunger? Why or why not?

Q2. What do you feel as you push the plunger?

3. This time, push the plunger of the syringe all the way to the end of the syringe. Suck water from the cup or container up to the 30-mL level of the syringe. Cover tightly the tip of the syringe with your thumb.

Q3. What do you feel as you push the plunger?

Q4. Compare what you felt when you pushed the plunger with the air and with the water?

Q5. Explain what you observe. You may represent your comparison by drawing an illustration of the syringe and the particles of air and another illustration of the syringe and the particles of water.

4. Pour ½ cup of tap water into one transparent glass bottles.

5. Pour the ½ cup of tap water in step #4 into another bottle or beaker. Observe carefully the flow of water.

Q6. Did water take the shape of the container?

6. This time, pour the water just on the flat surface of a dinner plate.

Q7. What do you observe? Write all your observations.

7. Examine a single piece of bottle cap. Put it inside the bottle. Observe carefully what happens as you transfer it by tilting the bottle into the dinner plate.

Q8. What do you observe? Write all your observations.

8. Pour ½ cup of rock salt or sand into the narrow-mouthed bottle. Observe carefully what happens to rock salt as you pour it into the bottle and when all of it has been transferred.

Q9. Did rock salt or sand take the shape of the bottle? Did the particles of rock salt change in shape?

Particle Models of the Three States of Matter

From Activity 3, you observed that you could slightly push the plunger of the syringe with air in it. You felt the springiness of the air inside the syringe which gives a hint about the distance between the particles of air. In other words, air, being a gas, can be compressed because there are large spaces between the particles so the particles can be made to come closer to each other. However, you were not able to push the plunger of the syringe with water in it. You felt the resistance of the water to being compressed. The plunger could not be pushed because water is not as compressible as air. The particles of liquid water are closer to each other and it is difficult to push them even closer to each other.

From the idea that matter is made up of particles and the situations that you observed, your drawings show how you "see" matter beyond what you can observe with your unaided eyes. You were creating your own mental picture and constructing **models**, which are drawings or diagrams that are representations of what is happening at a level beyond what your eyes can see. This is what science educators call the **sub-microscopic model** of representing an idea or concept, which you cannot observe with your senses or even aided by a simple microscope. From your discussions, you may have also thought of ways to make your models more consistent with the evidence you observed.

At this stage, it is possible that the mental models you have drawn do not perfectly match those that you see in books. Keep in mind that the models are not like the pictures taken by a camera. They are only representations of reality.

The particle model of matter shows that in gases, the particles move at random directions very quickly and travel in straight-line paths. In the process, they collide with one another and with the walls of the container. They change direction only when they rebound from the collisions. The distance between particles is large compared to the size of the particles. The attraction between particles is negligible because of the large distance between them. This explains why a gas spreads. Its particles fill all the available space in the container.

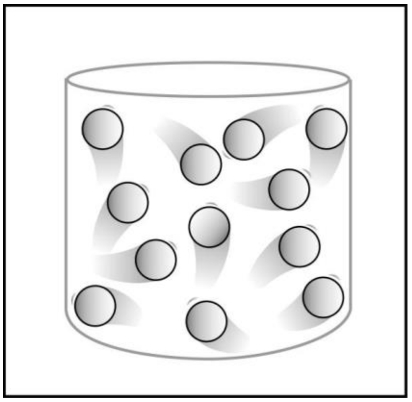
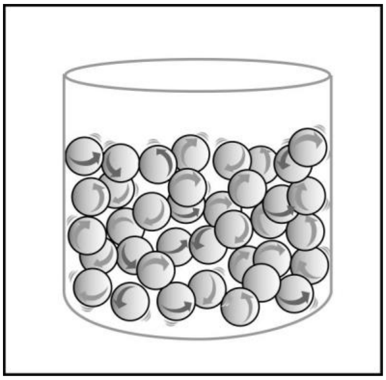


Figure 2. The particle view of a gas

Gases take the shape of the container because the particles are able to move freely to all parts of the container. They move freely because they are far apart and there is negligible attraction between them. This model also explains the compressibility of gases. The distances between particles are large and so there is room for the particles to move closer to each other.

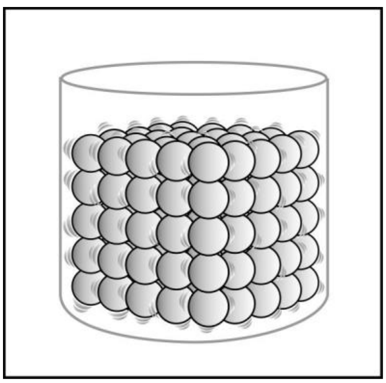
In liquids, the particles are closer to one another, nudging one another as they move. Since the particles are closer to one another, the attraction between particles is stronger than those in gases. The particles move and change positions but not as freely as those in a gas.

As you observed in the activity liquids can flow out of a container and can be poured into another while maintaining their volume. This happens because there are attractions among the particles of liquid which hold them together although not in fixed positions. These attractions also make it possible for liquids to have a definite volume. This is one major difference between liquids and gases, the particles are attracted to one another more strongly than the particles of gases are.



When you poured water and rock salt in separate containers, you observed that a liquid, such as water flows and it spreads out and takes the shape of the container. If you looked closely as you poured the rock salt, the little pieces of solid salt maintained their shape even as the entire sample may take the shape of the container.

Figure 3.The particle view of a liquid



Solids have definite shapes and volume because the particles are packed closely together in fixed positions. They vibrate a little but in these fixed positions. The particles cannot move around. The particles of solids are held together by strong forces. One common characteristic of both solids and liquids is that the particles are in contact with their neighbors, that is, with other particles. Thus they are incompressible and this commonality between solids and liquids distinguishes them from gases.

Figure 4. The particle view of a solid

There are other properties that you will learn in Grades 9 to 12 that will be useful for distinguishing among the states of matter. In general, the three states of matter differ because of the arrangement and motion of the particles in each state.

So far, based on Activities 1 to 3 and your teacher's explanation, you learned that matter is anything that has mass and volume and you now have a better "picture" or view of how the particles are arranged in the three states of matter: solid, liquid, and gas.

- Matter is made up of tiny particles.
- Particles of matter are moving all the time.
- These particles have spaces between them.
- The particles of matter attract each other.

These ideas are some of the features of what scientists call the **particle model of matter**.

In Activity 4, you will explain the changes taking place when liquid water is left in an open and in a closed container using the particle model of matter.

Activity 4
What changes take place when water is left in an open container? In a closed container?

Objectives:

After performing this activity, you should be able to:

1. describe what happens to water when it is left in an open container for some time;
2. represent through drawings/illustrations what happens to the particles of water when it is left in an open container;
3. describe what happens to water when it is left in a closed container for some time; and
4. explain the processes taking place at the sub-microscopic level.

Materials Needed:

1 cup tap water
3 pieces, watch glass or 2 pieces, shallow transparent plastic container with covers (used for condiments)
1 piece, 1 teaspoon or ½ measuring tablespoon

Procedure:

1. Pour 1 teaspoon or ½ tablespoon of tap water into the watch glass. This is container No.1. You can write "No. 1" on a piece of paper and place it under the watch glass. Cover container No.1 and set it aside.
2. Pour 1 teaspoon or ½ tablespoon of tap water into the second watch glass. This is container No. 2. Do not cover container No. 2.
3. Put container No. 2 beside container No. 1 in an area of your laboratory or room where these can be kept overnight.

4. During your next science class, discuss with your groupmates the following questions and write your answers in your notebook.

Q1. Describe what happened to the water in container No. 1.

Q2. Describe what happened to the water in container No. 2. Compare the volume of water left in container Nos. 1 and 2.

Q3. Where do you think did the water go? Describe this process by writing your description or drawing an illustration. Label the parts of your drawing. You can use “call outs” in your drawing.

Q4. Would anything happen differently if you heated container No. 2? Explain your answer.

Changes between a Liquid and a Gas

In Activity 4, you observed that the volume of water from an open container decreased after leaving it overnight. In fact, nothing of the 1/2 tablespoon of water was left on the watch glass. How do we explain this? Based on the particle model of matter, particles are always in motion. Note that the particles mentioned in this case are the molecules of water. These molecules have kinetic energies that differ from each other. Some particles are moving faster than others and therefore have higher kinetic energy and some are moving slower. So, even at room temperature, some molecules of water have enough kinetic energy to overcome the attraction of neighboring molecules and escape from the surface of the liquid and eventually move into the air. To break away from the surface of the liquid, the molecules must have at least some minimum kinetic energy. The process by which the molecules on the surface of a liquid break away and change into gas is called **evaporation.** Usually, it is described as the process where a liquid is changed into a gas.

As evaporation takes place, the water molecules which did not escape and were left in the liquid have a lower average kinetic energy than the molecules that escaped. The effect of this is the decrease in the temperature of the liquid water. Evaporation is a cooling process.

You can feel this cooling effect yourself when you apply acetone on your nails or rubbing alcohol on your arms. Acetone and rubbing alcohol are volatile liquids. They readily evaporate. As they evaporate, the molecules get heat energy from your body leaving you with a cool sensation.

It is important to remember that the evaporation of a liquid in a closed container is different from evaporation from an open container. In a closed container, no particles can escape into the air outside the cover of the container. In Activity 4, you may have observed that droplets of water formed under the watch glass which covered the second watch glass with water. So, evaporation still happens in a covered container. Some of the molecules of water on the surface of the liquid escape and go into the gaseous state. These molecules may then collide with the inner surface of the cover and as more and more of these molecules do so, some may stay on the cover, accumulate and form droplets. This process where a gas is changed into a liquid is called **condensation**. It is the reverse of evaporation.

In a closed container, the molecules of water continue to evaporate and condense, but there is no net change in the number of molecules in the liquid or in the gas phase. Molecules of water that previously evaporated are condensing, but other water molecules are evaporating.

There are many other examples of condensation that you may have observed. Condensation is responsible for ground-level fog that we see on some cold days or along the highway leading to Baguio, for your eye glasses fogging up when you go from an air conditioned room or vehicle to the outdoors on a hot day, and for the water that collects on the outside of your glass of cold drink.

In the next activity, you will represent your ideas through a written description, a cartoon, or simply an illustration and explain the changes taking place when water is heated or cooled using the particle model of matter.

Activity 5
What changes take place when water is heated or cooled?

Objectives:

After performing this activity, you should be able to:

1. describe what happens to water when it is heated;

2. describe what happens to water when it is cooled;

3. represent through drawings/illustrations what happens to the particles of water when it is heated and then cooled; and

4. explain the processes taking place at the sub-microscopic level.

Materials Needed:

100 mL tap water (or ½ cup tap water)
1 piece, beaker or Erlenmeyer flask, 200 or 250 mL
1 piece, small watch glass
1 piece, tripod

1 piece, wire gauze (without the asbestos)
1 piece, alcohol lamp
safety matches
1 marker pen (any color)

Procedure:

Part A. Boiling Water

1. Pour ½ cup or 100 mL of water into the beaker and mark the level of water outside the beaker.

2. Put the beaker with water on top of the tripod as shown in Figure 5.

3. Let the water boil using the alcohol lamp. Observe carefully what is happening to the water when it is already boiling.

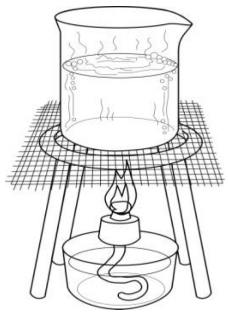


Figure 5.Setup for boiling water

Q1. Describe what you observe in the water inside the beaker and above the level of water.

4. You may do any of the following: write a description or draw a cartoon or illustration to demonstrate how the particles of water behave as they are heated.

Add to your skit or cartoon or illustration your answers to Q2 to Q5.

Q2. What do you think is inside the bubbles that form when the water boils? Where did they come from?

Q3. If you keep the water boiling for more than 10 minutes, what do you think will happen to the amount of water in the beaker? Why?

Q4. Where did the water go?

Q5. Can you explain by illustration how the water changes from liquid to gas? What is happening to the particles of water?

5. After boiling the water for 10 minutes, remove the alcohol lamp and put off the flame.

Part B. <u>Cooling Water</u>

1. Using the hot water that has boiled from Part A, cover the beaker with watch glass.

Q6. Describe what you observe in the water inside the beaker and at the bottom of the watch glass.

You may do any of the following: write a description or draw a cartoon or illustration to demonstrate how the particles of water behave as they are heated.

Add to your skit or cartoon or illustration your answers to Q6 to Q9.

Q7. Where does the water at the bottom of the watch glass come from?

Q8. Can you explain by illustration how the water changes from gas to liquid?

Q9. Describe what is happening to the particles of water.

In Part A, Activity 5, you observed that after boiling water for some time, the amount of water inside the beaker decreased. As the water is heated and the temperature of the water rises, the molecules gain more kinetic energy and they move faster. More molecules therefore have the energy to overcome the forces of attraction of the adjacent molecules. These molecules escape to the gaseous phase. This is *evaporation*.

This evaporation and formation of gas can happen even below the surface of the liquid. When this happens bubbles are formed, rise to the surface and escape into the air. This is the bubbling phenomenon that you see when water boils.

In Part B, Activity 5 of this module, you observed that as the water began to cool, droplets formed under the watch glass that covered the beaker containing hot water. Where did these droplets come from? The molecules that escape from the liquid and go into the gaseous phase is called **vapor** and in this case, **water vapor**. The water vapor rises and some molecules touch the glass. The glass is cooler than the boiling water so some of the heat energy of the vapor molecules are transferred to the glass, in effect, cooling the water vapor. When a gas is cooled, the motion of the particles slows down. If the particles lose enough energy, their attraction for each other can overcome their motion and cause them to associate with one another to become a liquid. This is the liquid observed under the watch glass in the above activity. This process is called *condensation*.

Recall two aspects of the particle model of matter: particles are moving all the time and there are forces that act between the particles. These principles can explain at the sub-microscopic level what you observed in Part B, Activity 5. Not all of the water changed from liquid to water vapor. There was still liquid water left in the beaker. Some of the molecules do not have the energy to overcome the forces of attraction of the neighboring molecules. In addition, some of the molecules of water that escaped to the vapor phase, hit the molecules on the surface of the liquid and if they do not have sufficient energy, the attraction of molecules on the surface cause them to stay and join the liquid phase.

In Activity 6, you will draw a model and explain the changes taking place when ice is changed to liquid water using the particle model of matter.

Activity 6
What changes take place when ice turns into liquid water?

Objectives:

After performing this activity, you should be able to:

1. represent through drawings or cartoons what happens to the particles of ice when it turns to liquid; and

2. explain the processes taking place using the particle model of matter.

Materials Needed:

2 pieces, ice cubes
1 piece, watch glass or saucer

Procedure:

1. Put one piece of ice cube on a watch glass or small saucer.

2. Observe what happens to the ice cube after 2 minutes.

3. You may do any of the following: write a description or draw a cartoon or illustration to show how the particles of water behave as ice changes to a liquid.

Q1. Explain what is happening to the particles of water in ice as it turns to liquid using the particle model of matter.

Q2. Explain what will happen to the liquid on the watch glass or saucer if it is transferred into a small container and left inside the freezer after a few hours or overnight?

Changes between a Solid and a Gas

In Activity 6, you observed that after about 15 to 20 minutes, the ice (solid water) on the watch glass or saucer turned into liquid water. The ice cube, which was taken from the freezer is at a lower temperature than the surrounding room temperature. Some of the heat energy of the surroundings is transferred to the water molecules in the ice. This increases the kinetic energy of the molecules and as the heat transfer continues, the particles gain more and more kinetic energy. The molecules vibrate faster and faster and at some point have enough energy to overcome the forces that hold them in their fixed places in the solid. Since the molecules vibrate so fast, they break away from their fixed positions. The arrangement of the water molecules in ice gradually becomes disorganized and the solid where the molecules are in fixed positions turns to liquid where the molecules are more free to move. This transformation process in which a solid is changed to a liquid is called **melting**.

On the other hand, when you put liquid water inside a freezer, the cooling system of the refrigerator removes heat energy from the water molecules as a result of which they have less kinetic energy and move more slowly. As more and more heat is removed and as the molecules move more slowly, the forces of attraction between the molecules cause the molecules to be aligned. As this removal of heat continues, the molecules lose so much energy that they are not able to move from place to place but only able to vibrate in place. In time, the liquid water becomes solid water, which is ice. **Freezing** is the process in which a liquid is changed to a solid.

Note that liquid water that freezes is still water. Similarly, ice that melts is still water. This is why after melting an ice cube, you can freeze the liquid water back to ice. In other words, the same molecules of water are involved when these changes occur.

In Activities 1 to 6, you have learned the four basic aspects of the particle model of matter. These are: (1) matter is made up of very small particles; (2) matter is made up of particles that are constantly moving; (3) there is empty space between the particles; and (4) there are forces that act between the particles. Using this model, you were able to infer that the arrangement and motion of the particles of matter, as well as the attraction between them change when they change from one state to another. However, the same particles of matter are involved when these changes happen. The particle model of matter can explain the following phase changes: evaporation, boiling, condensation, melting, and freezing.

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Suggested time allotment: 10 hours

Unit 3
MODULE
2

ATOMS: INSIDE OUT

Overview

In module 1, you learned that matter is made up of atoms which are too small to see with the unaided eye or even with the use of the ordinary light microscope. When the idea of the atom was conceived by the ancient Greek philosophers, they thought the atom is indivisible, that it has no parts.

Scientists have proven, however, that the atom is composed of even smaller particles. From experiments conducted in the latter part of the 19^{th} century to the early half of the 20^{th} century, scientists collected evidence that atoms are composed of three types of particles, namely, (1) **protons**, (2) **electrons** and (3) **neutrons**. These components of the atom are collectively referred to as **subatomic particles**. In recent years, scientists have discovered that protons and neutrons consist of even smaller particles. There are still many things about the atom and what is inside it that scientists are discovering. These extremely small particles are being studied using an extremely big structure that serves as their instrument. The thick black circle in Figure 1 is the entire scientific instrument and its circumference is precisely 26.659 kilometers and its depth is about 100 meters. To give you a better idea how big this structure is, find from the map a place which is about 27 km from your own town. Working in a laboratory that aims to uncover the tiniest bits of matter that make up all that we see around us must be truly exciting! Who knows, you might join this group of scientists and make more discoveries about the atom. Inspiring and challenging, perhaps? To get you started, prepare yourself to turn the atoms inside out!

Figure 1. The Large Hadron Collider at the CERN complex, Geneva, Switzerland. Photograph courtesy of CERN. Retrieved from http://cds.cern.ch/collection/Press%20Office%20Photo%20Selection?ln=en

What makes up an atom? How do these components differ from each other? How are these components arranged inside the atom? How is an atom different from an ion?

In the earlier grades, you learned about magnets. A magnet has two ends, two poles, the north and the south. Put the north ends of two magnets next to each other and the magnets move apart. How about putting the two south ends next to each other? Yes, the same observation would be made as when both north ends are next to each other. How about when you place the north and south ends next to each other, what will happen? They attract each other. These observations indicate that *like ends or poles repel, unlike ends or poles attract*. Electric charges (or simply charges), either positive charge or negative charge, behave similarly, that is, *like charges repel or push away each other and unlike charges attract or pull toward each other*. Keep this kind of behavior in mind, as you do the first activity.

Activity 1
"Charge" it to experience!

Objectives:

After performing this activity, you should be able to:

1. observe that objects may attract or repel each other,

2. infer that objects may carry positive and negative charges, and

3. deduce that neutral objects contain positive and negative charges

Materials Needed:

meterstick or any meter-long stick
balloons
string
chairs or any stand for the stick
glass (from a picture frame)
cloth (flannel or silk cloth)

Procedure:

1. Inflate the two balloons. Tie each using a length of string. Place the meter-long stick across two chairs. Suspend the two balloons so that they hang freely about two inches apart.

2. With each hand holding one balloon, rub the balloons simultaneously against your hair several times. Let go of the balloons. Observe.

Q1. What happened with the balloons?

Q2. Did the balloons acquire the same charge or different charges? What made you say so?

3. Rub the piece of glass with a silk cloth. Bring the piece of glass between the two balloons. Observe.

Q3. What happened with the balloons?

Q4. Does the glass have a different or same charge as the balloon? What made you say so?

From the activity above, you have “experienced” that objects, even they seem to be neutral, can carry “charges”. In fact, you were able to charge the objects by rubbing them against another object; just like when you rubbed the balloons onto your hair. You can infer that after you have rubbed the balloons, they acquired a charge since they pushed away each other. You can even say that the balloons acquired the same charge. They have indeed! The balloon, or synthetic rubber, the material the balloon is made of, acquire negative charges when rubbed. Have you experienced the same with your hair after brushing it? Did you observe some unusual behaviour, too? Was it a “hair-raising” experience? Why do you think this happened?

How about the rubbed glass? What charges do you think the glass carried after it was rubbed with the cloth? Yes, the glass was positively-charged since the negatively-charged balloons were attracted towards the glass. From here, you can infer that objects are **electrically neutral**, or simply, neutral, but they carry electrical charges.

But where do all these charges come from? In module 1, you have learned that all matter, including the objects that you used in Activity 1, are made up of atoms. Atoms, of which all objects are made, are electrical in nature. Atoms contain particles with positive and negative charges. The proton carries a positive charge (+1). The electron carries a negative charge (-1). Atoms, in their most stable state are neutral with an equal number of protons and electrons. So, let us say an atom has 5 electrons, how many protons does this atom have? How about if the atom has 64 protons, how many electrons does this atom have?

The other particle in atoms is the neutron which does not carry any charge or is neutral; as you may have guessed from the name it was given. Consider an atom which has six protons, six electrons and six neutrons, is the atom electrically neutral? If instead the atom has six protons, six electrons and eight neutrons, is it still neutral? Does the number of neutrons affect the charge of the atom? With the charges of the three subatomic particles in mind, what could be the reason that among the three subatomic particles, it was the neutron which took the longest time to be discovered? In fact, it was detected 30 years after the electron and the proton were discovered.

The properties of the three subatomic particles are summarized in Table 2. One of their properties is their masses. In the next activity, you will compare the masses of the subatomic particles and ascertain which among them contributes the most to the overall mass of an atom.

Table 2. Some properties of the three main subatomic particles

Subatomic particle (symbol)	Charge	Mass, grams	Location in the Atom
Electrons (e^-)	-1	9.109×10^{-28}	Outside nucleus
Protons (p^+)	+1	1.672×10^{-24}	Nucleus
Neutrons (n^0)	0	1.675×10^{-24}	Nucleus

Activity 2
The big difference

Objectives:

After performing this activity, you should be able to:

1. compare the masses of the subatomic particles using different ways of visual representation
2. infer which subatomic particle contributes to the mass of the atom

Materials Needed:

pencil/pen
crayons or colored pencils

Procedure:

1. Refer to the masses of the subatomic particles in Table 2. Arrange the subatomic particles in increasing mass.

Q1. Which subatomic particle is the lightest?

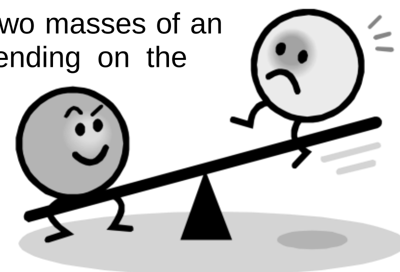
Q2. Which subatomic particle is the heaviest?

Q3. Which subatomic particles have almost the same mass?

2. Show a comparison of the masses of the three subatomic particles using a bar graph. Refer to Figure 2 in the next page, assuming that the first bar represents the mass of the proton; draw the bars to represent the masses of the neutron and the electron. Take note that the masses are expressed in the -28 exponent.

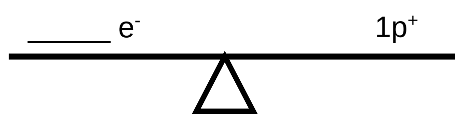
3. This time, using a pie chart, show the proportion of the masses of the subatomic particles for an atom composed of only 1 proton, 1 neutron and 1 electron.

4. A seesaw can show a comparison between two masses of an object. A seesaw goes up and down depending on the mass it carries on each side.



Q4. How does the mass of the neutron compare with the mass of the proton? Using circles to represent the particles show the comparison by drawing a seesaw with the particles on it.

Q5. How many electrons should be placed on one side of the seesaw to balance it if the other side has 1 proton on it, like the one shown below? Write the number on the space provided in the illustration below.



5. Take a look again at the different visual representations you have made.

Q6. Which subatomic particle/s make/s up most of the mass of the atom?

In the activity above, you have visually compared the masses of the three subatomic particles. You have “seen” that protons and neutrons are “massive indeed”. Electrons are very much lighter than the protons and neutrons, to the point that its mass does not significantly contribute to the mass of the entire atom. In effect, the mass of the electron is negligible.

The massive part of the atom, then, comes from the masses of the protons and neutrons. Collectively, the protons and neutrons are called **nucleons**. The nucleons, tightly packed together, form the **nucleus** in the center of the atom. Thus, most of the mass of the atom is contained in its nucleus. In the succeeding activities, you will learn more about the nucleus and how it was discovered.

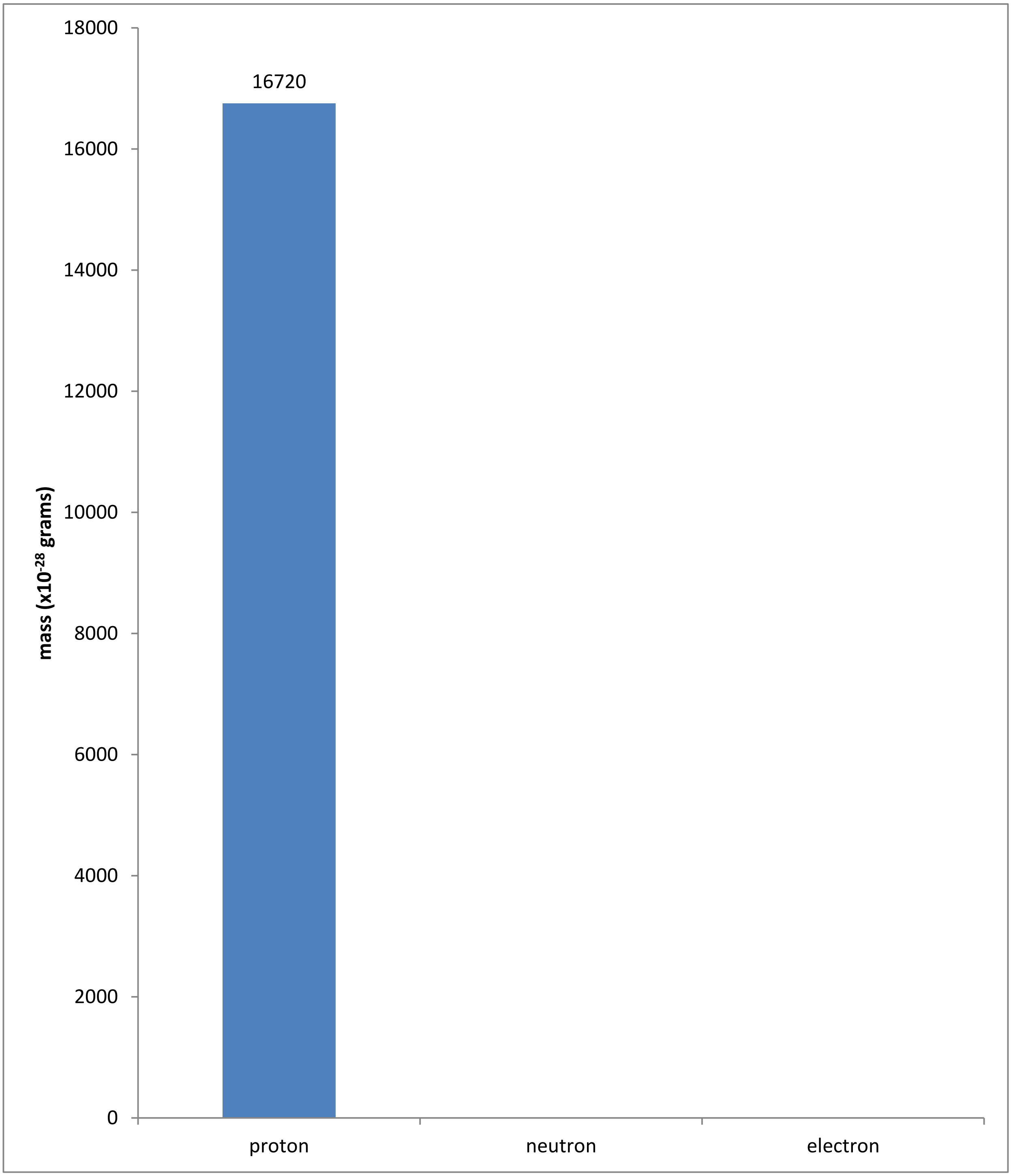


Figure 2. Masses (expressed in $x10^{-28}$ grams) of the subatomic particles

Activity 3
Small but terrible

Objectives:

After performing this activity, you should be able to:

1. simulate and describe Thomson's model of the atom
2. simulate and describe Rutherford's model of the atom
3. deduce that scientific models may change over time

Part A

Materials Needed:

Box containing a marble and a regularly shaped object fixed in place

Procedure:

1. Get the activity box from your teacher. Write the box number on your worksheet. Inside the box are the "mystery object" which is fixed in place and one marble. Without opening the box, guess the shape, size and location of the mystery object.

Q1. What is the shape of your "mystery object"?

Q2. What is the size of the "mystery object"? Draw a picture of the "mystery object" showing its size relative to the box.

Q3. Where is it located in the box? Draw a picture of the "mystery object" showing its location within the box.

Q4. How were you able to infer the shape, size and location of the "mystery object" in the box?

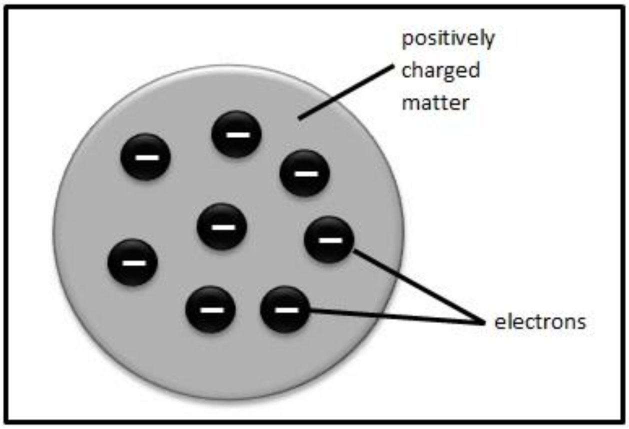
2. Open the box and check how close you are in guessing the size, shape and location of the "mystery object".

Q5. How close was your guess? If given the chance to guess another "mystery object", will you change your strategy? If yes, what changes will these be?

3. With the permission from your teacher, you may again try to guess another "mystery object".

How was your experience in Part A? Perhaps, you had felt the same excitement as what our scientists felt when they are trying to determine what was inside the atom, its structure. The excitement comes from guessing about something that is unseen, much like guessing what is inside a box that you received as gift on your birthday! The scientists had to look for ways to find out what the eyes cannot see, similar with what you did in Part A.

When the idea of the atom was first proposed by the ancient Greeks, they thought it was a particle with no parts. However, towards the 19^{th} century, J.J. Thomson was able to discover that atoms have negatively-charged particles, which he called electrons. It led him to propose a new model for the atom, which he called the **plum pudding model**. Thomson proposed that the negatively-charged electrons were embedded in a kind of cloud or soup of positive charge, as shown in the figure on the right. Since plums and puddings are not commonly known in the Philippines, it may work better for you that we use the other name for the model, the **raisin bread model**.



In science, models, based on observations from experiments are tested further, sometimes by other scientists, to determine their validity. A group of scientists composed of Ernest Rutherford, Johannes "Hans" Wilhelm Geiger and Ernest Marsden tested Thomson's model by bombarding a very thin sheet of gold foil with positively-charged alpha particles. Their experiment is referred to as the **alpha particle scattering experiment**. In the next parts of the activity, you will simulate parts of the experiment that the group of Rutherford did.

Part B

Materials Needed:

one piece of 25 centavo coin
paper, any small piece will do
smooth, clean table, counter or floor

Procedure:

1. Tear 20, very small pieces of paper, the size of mongo beans.

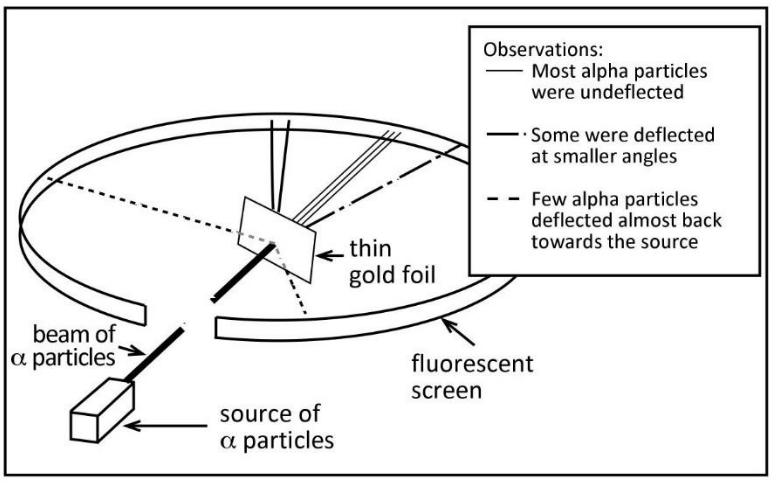
2. Scatter the pieces in a circle on the floor, about one foot in diameter. Imagine these to be the electrons in the Thomson's raisin bread model of the atom.

3. As forcefully as you can, slide the coin to hit the circle of paper pieces. Imagine the coin to be the high speed alpha particle in Rutherford's experiment.

Q1. What do you observe? What happened to the coin?

4. If you repeat what you did with the coin and the paper pieces many times, do you think you will make the same observation as you did above about what happens to the coin?

Using a setup similar to the figure below, Rutherford and his coworkers expected all of the alpha particles to travel undeflected through the atoms of gold like the coin in the above activity. They observed that most of the alpha particles did go through the gold foil undeflected. But what surprised them was that there were a few alpha (α) particles that practically bounced back towards the source and some that were deflected at smaller angles. Rutherford was reported to have exclaimed, "*It was as if you fired a 15-inch shell at a sheet of tissue paper and it came back to hit you.*"



Recall what happened in Part A. How did you manage to know some information about the mystery object? Perhaps, you guessed by the way the marble is "bumping" the mystery object. You may even had a guess on where the mystery object is possibly located within the box. Perhaps, this guess also came from the "non-bumping" of the marble to anything except the sides of the box. Similarly, the way the alpha particles "bumped", or did not "bump", the particles in the atoms of the gold foil led Rutherford's team to propose another model for the atom, the **nuclear model**. In the raisin bread model, where the electrons with very small mass were scattered in a cloud of positive charge, there was no region within the atom where there would be an appreciable net concentration of charge that would cause the alpha particles to be deflected. To account for the few deflections and the rare occasions of very large deflections, Rutherford, in 1911, suggested a different structure of the atom where all the positive charge and nearly all the mass of the atom were concentrated in a very tiny region called the nucleus at the center of the atom. The rest of the atom, where the tiny electrons with very small mass moved, was largely empty space through which the alpha particles could travel undeflected.

This model replaced the one proposed by Thomson and is the model that we hold to this time, with respect to the placement of the nucleus in the atom. In Part C, you will simulate the alpha particle scattering by the gold foil in Rutherford's experiment using his model of the atom.

Part C

Material Needed:

pencil

Procedure:

1. Refer to Figure 3 in the next page. Using this schematic representation of the atoms of the gold foil, draw the path of the positively-charged alpha particles as they move through the atoms.

Q1. What happens to a positively-charged alpha particle that comes near the positively-charged nucleus?

Q2. What happens when the positively-charged alpha particle directly hits the positively-charged nucleus?

2. The representation of the gold foil that has been given to you is not quite to scale. The nucleus is very tiny compared to the size of the atom. The ratio of the size of the nucleus to that of the atom is 1:100,000. If the nucleus were about 1 mm in diameter, the atom would have a diameter of 100 meters, which is about the height of 30-story building.

Q3. Imagining this relative size of the nucleus compared to the atom, would there be many more or fewer alpha particles that would pass through the gold foil undeflected compared to the number in your schematic representation?

Q4. What do you think are the chances of the alpha particle directly hitting the nucleus?

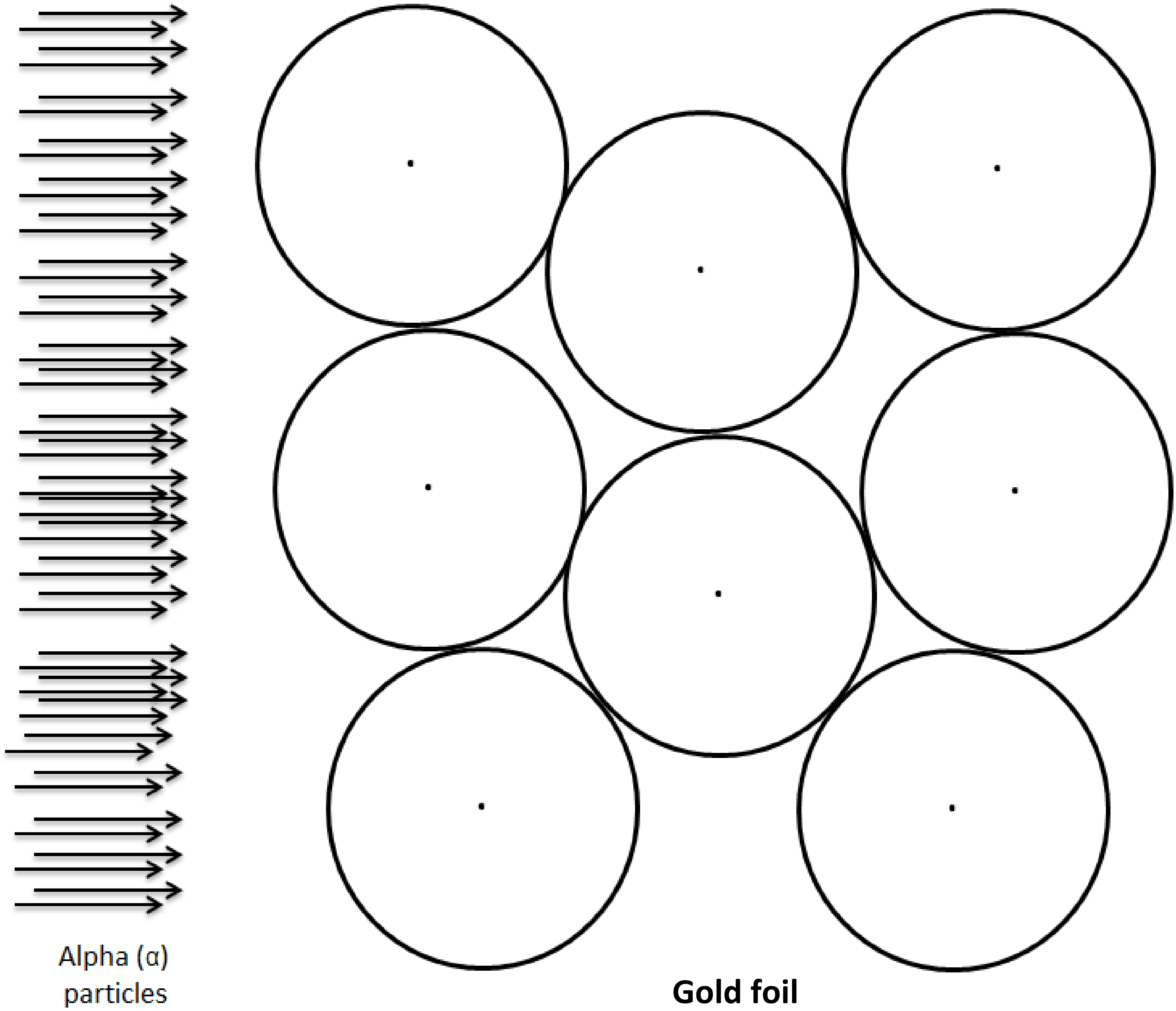


Figure 3. Schematic representation of the atoms of a gold foil

The nuclear model of the atom proposed by Rutherford in 1912 is still the picture of the atom that we hold today. Observations made afterward in experiments concerning the atom support the model.

The other puzzle about the atom concerns the electrons. Imagine again the atom as 100 meters in diameter, the nucleus, around one millimetre in diameter at the center and the electrons are in this vast space around the nucleus. Where in this vast space are the electrons? Are they moving? How do they move? How fast do they move?

One of the models of the electrons in atoms is the planetary model where the electrons were thought to move in orbits around the nucleus similar to the way planets like the earth move around the sun. This has since been found to be incorrect. The behaviour of electrons in the space around the nucleus is not simple to describe. What we do know, however, are the following: (1) The electron although it is negatively charged does not collapse into the positively charged nucleus; (2) There is attraction between the nucleus and the electron, evidence of which is that energy is required to remove an electron from the atom.

Notwithstanding the complex behaviour of electrons in atoms, we continue to use a model of electronic structure (or the way electrons are "arranged" in the atom) to help us understand and study the way atoms combine to form the millions of compounds discovered to date.

So far, you have learned about the three subatomic particles — protons, electrons and neutrons — and how they are arranged in the currently accepted model of the atom. Among these subatomic particles, it is the number of protons that identify the atoms of an element. All atoms of an element contain the same number of protons in their nuclei. This number is the element's **atomic number**. In the next activity, you will refer to the periodic table in determining the atomic number. Notice that no two elements have the same atomic number.

Activity 4
What's in a number?

Objectives:

After performing this activity, you should be able to:

1. locate the atomic number in a periodic table,
2. identify the subatomic particles associated with mass number,
3. determine the number of neutrons from the mass number,

4. define an isotope,
5. interpret shorthand notations for isotopes and atoms,
6. infer that ions are formed from the removal or addition of electron/s,
7. evaluate the overall electrical charge of an atom, and
8. make an inventory of subatomic particles of a given element.

Materials Needed:

paper
pen/pencil
Periodic Table

Procedure:

1. Refer to the periodic table at the end of this module. Locate the **atomic number**.

Q1. What is the element with an atomic number of 15?

Q2. How many protons does the atom of this element have?

Q3. How many protons are there in an atom of aluminum?

Q4. Which element has the smallest number of protons in its atom?

2. While the number of protons is the same with atoms of a particular element, the number of neutrons may vary. Atoms having the same number of protons but different number of neutrons are referred as **isotopes**. The isotopes are identified through their **mass number** which is the sum of the number of protons and the number of neutrons in an atom. A shorthand notation for isotope includes the element's symbol and mass number, for instance, Ca-40.

   Consider two isotopes of carbon, C-12 and C-13.

Q5. How many protons are there in the C-12 isotope? How about the number of neutrons?

Q6. How many protons are there in the C-13 isotope? How about the number of neutrons?

3. Atomic mass is the mass of an atom of a particular element. It is the average of the mass numbers of the naturally occurring isotopes of the element multiplied with their respective abundance. You will not compute for atomic mass. However, you have to know, at least, where to find it in the periodic table.

   Refer to the periodic table at the end of this module.

Q7. What is the atomic mass of magnesium (Mg)? How about for potassium (K)?

4. The figure on the right shows another shorthand notation. Information on the subatomic particles may be derived from this shorthand. The base is the element's symbol. The left subscript denotes the atomic number, therefore the number of protons may be known. The superscript at the left denotes the mass number wherein the number of neutrons may be derived. On the other hand, the superscript at the right denotes the charge wherein the number of electrons may be determined. When there is no superscript at the right, it means that the charge is zero (0).

$${}^{7}_{3}\mathrm{Li}^{+1}$$

Atoms may gain charges, as you have experienced in Activity 1. This happens when electrons are lost or gained by the atom. When this happens, the atom become an **ion**.

Consider the lithium ion shown in the notation above.

Q8. How many protons are there in the lithium ion?

Q9. How many neutrons are there in this lithium ion?

Q10. How many electrons are there in the lithium ion?

5. Complete the table below.

Isotope	**Element Name**	**# of p^+**	**# of e^-**	**# of n^0**	**Charge**
B-6	Boron	5		1	0
N-14	Nitrogen		7		0
	Fluorine	9		10	-1
	Neon		10	10	
Mg-24		12	10		
Al-27					+3
Si-28			14		
S-32					0
K-35					+1

6. Using any reference, write the shorthand notation showing mass number and atomic number for all the naturally occurring isotopes of iron.

In the next module, you will learn more about the atomic structure in relation to the periodic table. You will notice that a pattern emerges from the way the atoms are arranged in the table. Hopefully, this module sparked your interest and you are excited to know more about the atom.

PERIODIC TABLE

Key

atomic number **Symbol** name atomic mass (gram/mol)

1	2	3	4	5	6	7	8	9
1 H hydrogen 1.008								
3 Li lithium 6.942	4 Be beryllium 9.012							
11 Na sodium 22.99	12 Mg magnesium 24.31							
19 K potassium 39.10	20 Ca calcium 40.08	21 Sc scandium 44.96	22 Ti titanium 47.90	23 V vanadium 50.94	24 Cr chromium 52.00	25 Mn manganese 54.94	26 Fe iron 55.85	27 Co cobalt 58.93
37 Rb rubidium 85.47	38 Sr strontium 87.62	39 Y yttrium 88.91	40 Zr zirconium 91.22	41 Nb niobium 92.91	42 Mo molybdenum 95.94	43 Tc technetium (98)	44 Ru ruthenium 101.1	45 Rh rhodium 102.9
55 Cs cesium 132.9	56 Ba barium 137.3		72 Hf hafnium 178.5	73 Ta tantalum 181.0	74 W tungsten 183.9	75 Re rhenium 186.2	76 Os osmium 190.2	77 Ir iridium 192.2
87 Fr francium (223)	88 Ra radium (226)		104 Rf rutherfordium (261)	105 Db dubnium (262)	106 Sg seaborgium (266)	107 Bh bohrium (264)	108 Hs hassium (277)	109 Mt meitnerium (268)

57 La lanthanum 138.9	58 Ce cerium 140.1	59 Pr praseodymium 140.9	60 Nd neodymium 144.2	61 Pm promethium (145)	62 Sm samarium 150.4
89 Ac actinium (227)	90 Th thorium 232.0	91 Pa protactinium 231.0	92 U uranium 238.0	93 Np neptunium (237)	94 Pu plutonium (244)

*newly named elements, as of June 2011. For more information, please access http://iupac.org/publications/pac/83/7/1485/

OF ELEMENTS

10	11	12	13	14	15	16	17	18
								2 He helium 4.003
			5 B boron 10.81	6 C carbon 12.01	7 N nitrogen 14.01	8 O oxygen 16.00	9 F fluorine 19.00	10 Ne neon 20.18
			13 Al aluminium 26.98	14 Si silicon 28.09	15 P phosphorus 30.97	16 S sulfur 32.06	17 Cl chlorine 35.45	18 Ar argon 39.95
28 Ni nickel 58.70	29 Cu copper 63.54	30 Zn zinc 65.37	31 Ga gallium 69.72	32 Ge germanium 72.59	33 As arsenic 74.92	34 Se selenium 78.96	35 Br bromine 79.91	36 Kr krypton 83.80
46 Pd palladium 106.4	47 Ag silver 107.9	48 Cd cadmium 112.4	49 In indium 114.8	50 Sn tin 118.7	51 Sb antimony 121.8	52 Te tellurium 127.6	53 I iodine 126.9	54 Xe xenon 131.3
78 Pt platinum 195.1	79 Au gold 197.0	80 Hg mercury 200.6	81 Tl thallium 204.4	82 Pb lead 207.2	83 Bi bismuth 209.0	84 Po polonium (209)	85 At astatine (210)	86 Rn radon (222)
110 Ds darmstatdtium (281)	111 Rg roentgenium (280)	112 Cn copernicium (285)	113 (Uub) (277)	114 Fl flerovium* (289)	115 (Uuq) (289)	116 Lv livermorium* (292)	117 (Uuh) (292)	118 (Uuo) (294)

63 Eu europium 152.0	64 Gd gadolinium 157.2	65 Tb terbium 158.9	66 Dy dysprosium 162.5	67 Ho holmium 164.9	68 Er erbium 167.3	69 Tm thulium 168.9	70 Yb ytterbium 173.0	71 Lu lutetium 175.0
95 Am americium (243)	96 Cm curium (247)	97 Bk berkelium (247)	98 Cf californium (251)	99 Es einsteinium (252)	100 Fm fermium (257)	101 Md Mendelevium (258)	102 No nobelium (259)	103 Lr lawrencium (260)

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Link

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Suggested time allotment: 5 to 6 hours

Unit 3
MODULE
3

PERIODIC TABLE OF ELEMENTS

Overview

Scientists have always searched for patterns, regularities and symmetries in nature. If a pattern can be discovered, information and data can be arranged and organized in ways that will make it more understandable, meaningful, and useful. An excellent example of this is the periodic table. In Grade 7, you learned about the periodic table. The elements, the building blocks of matter, are listed in that table. In Module 2, you learned that the atoms that make up these elements are identified by their atomic number. In this module, you will learn that elements were arranged in the periodic table in rows and columns according to increasing atomic numbers. This arrangement was based on properties of elements which were found to be repeated regularly through the elements arranged according to increasing atomic number. The properties were recurring periodically, hence, patterns in the properties are observed. You will recognize this incredible feature of the periodic table in this module, as you explore its full potential as a source of information about the elements. You might even find it like a road map as you journey in your chemistry class. It would be helpful to keep it handy all the time.

How did the Periodic Table develop?

What information about elements can be obtained from this organizing tool?

The periodic table was developed as a result of years of painstaking work by different scientists. Its present form was a result of meticulous and thorough study by scientists. The first activity provides you an experience similar to those of the early scientists who developed the periodic table.

Activity 1
Tracking the path and constructing the periodic table

Objectives:

After performing this activity, you should be able to:

1. trace the development of the periodic table; and

2. describe how the elements are arranged in the periodic table.

Materials Needed:

paper
whole manila paper
pencils or pens
ruler
masking or adhesive tapes
element cards provided by the teacher (3 cm x 5 cm)

Procedure:

Part A

1. Element cards are posted on the board. The element's properties and the compounds it can form are listed in each card. As a class, go over each card. Notice that the cards are arranged in increasing atomic mass. While keeping the order of increasing atomic mass, put the elements with similar properties in the same column.

Q1. How many groups of elements were formed?

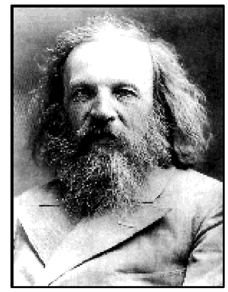
Q2. What criteria did you use to choose which group an element belongs to?

Q3. Are there any exception/s to these trends? If so, which elements break the trend? Why did your group arrange these elements the way you did?

Q4. Are there any gaps in your arrangement? Where are they? What do you think these gaps might mean?

The development of the Periodic table could be traced back in 1817 to the work of Johann Dobereiner, a German chemist who formed the triads of elements with similar properties like the triad of calcium, barium and strontium. In 1863, John Newlands, an English chemist proposed the Law of Octaves. He based his classification of elements on the fact that similar properties could be noted for every eight element when they are arranged in order of increasing atomic masses. Around 1869 two scientists determined a way to put the elements in order. Lothar Meyer and Dmitri Mendeleev both came up with periodic tables that showed how elements should be grouped. It is interesting to note that these two scientists did not personally know each other, yet they came up with the same conclusions. Both scientists were teachers living and working in different places. Meyer lived and worked in Germany while Mendeleev in Russia. Both arranged the elements in order of increasing atomic mass while putting in groups those with similar properties. Both of them also left blank spaces in their tables, believing that these spaces would be filled later with elements yet to be discovered.

Lothar Meyer



Dmitri Mendeleev

Part B

1. Using the table of elements you have created in Part A, place in that table the additional element cards that your teacher will give you.

Q5. How did your table of elements change each time you added new elements?

Q6. How is the table of elements you prepared similar to the modern periodic table? How is it different?

Q7. How do you explain the fact that tellurium comes before iodine in the modern periodic table, though it has a higher atomic mass than iodine?

Q8. Mendeleev predicted the existence of gallium and germanium because of the gaps in his table. Why do you think Mendeleev did not predict the existence of the noble gases?

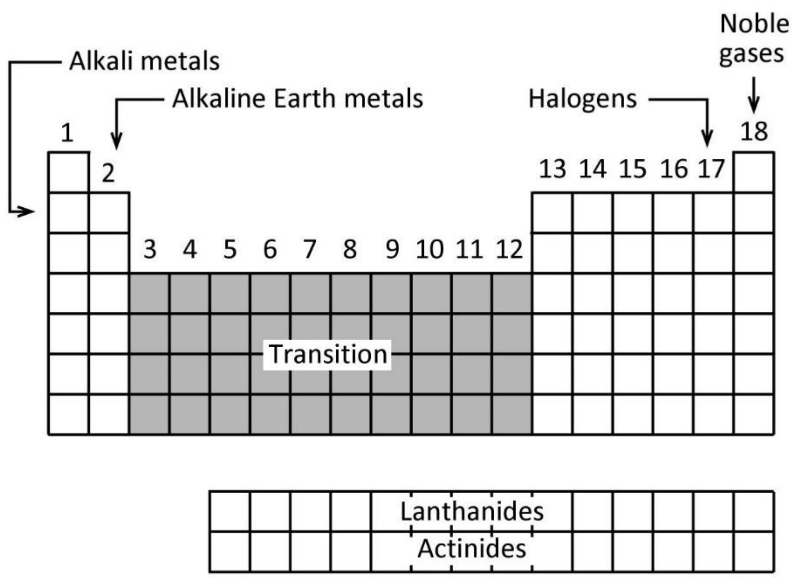
Q9. Refer to the modern periodic table. Suppose 2 new elements were discovered with the atomic numbers 120 and 121. Where in the Periodic table do you think you would place these new elements?

Q10. Suppose a new element X is known. It forms a compound with chlorine, and the formula of this compound is XCl_4. What group or family do you think this element would belong?

In the activity above, you had the experience of how the organization of the elements in one table was truly a herculean task. As more information was gathered about existing and newly discovered elements, irregularities were observed. Some newly identified elements had properties that did not match those of the groups already included in the periodic table. To fit into the right groups, the positions of a few elements had to be rearranged. There were even elements that had to be placed in the table as a new group. The table was thus revised.

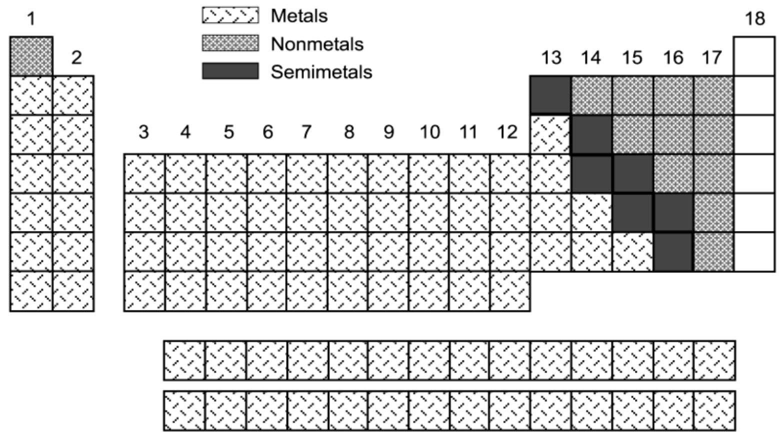
Later, in 1914, Henry Moseley, an English physicist observed that the order of the X-ray frequencies emitted by elements follows the ordering of the elements by atomic number. This observation led to the development of the modern **periodic law** which states that the *properties of elements vary periodically with atomic number*. Recall what you learned in Module 2 that atomic number is equal to the number of protons in the nucleus of an atom. The atomic number is a common characteristic of all atoms of an element.

The modern periodic table organizes elements in such a way that information about the elements and their compounds are easily revealed. The vertical columns of the periodic table, called **groups**, identify the principal **families** of elements. Some families have their special names. Refer to the figure on the right, Group 1 is named as the *alkali metals*, Group 2 as the *alkaline earth metals*, Group 17 as the *halogens* and Group 18 as the *noble gases*. Groups 13 to 16 are named based on the first element found in their families. Thus Group 16 is called the Oxygen Group. The horizontal rows or **periods** are numbered from the top to bottom. For example, the elements *lithium* (Li) across *neon* (Ne) form Period 2.There are 7 horizontal rows or periods in the periodic table.



The elements are grouped into blocks or series in the periodic table. In the later grades, you will learn how elements were grouped in blocks. Refer to the figure above, Group 3 to Group 12 constitutes one block wherein elements in this block are referred as the **transition elements.** The **lanthanides** and **actinides** are special series of elements but are also part of the transition block; they are also called the **inner transition elements**. Elements from the taller columns (groups 1, 2, and 13 through 18) are called the **representative elements** or *main groups* of the periodic table.

This arrangement allows us to study systematically the way properties vary with the element's position in the table. Similarities and differences among the elements are easier to understand and remember.



Recall what you learned in Grade 7. We can use the periodic table to identify the known elements as metals, nonmetals, and semimetals or metalloids, as shown in the figure on the right. A stair step line separates metals and nonmetals.The majority of the elements on the left side of the table are metals. The nonmetals are confined to the right side of the table. Moreover, you have learned in Grade 7 that the elements along the stair step line are the semimetals. Semimetals have the appearance and some properties of a metal but behave like a nonmetal in certain instances. The seven elements commonly regarded as semimetals are boron, silicon, germanium, arsenic, antimony, tellurium, and polonium. Boron, although not resembling a metal in appearance, is included because it resembles silicon. Silicon, germanium, and antimony, act as semiconductors, which are important in solid-state electronic circuits. *Semiconductors* are insulators at lower temperatures, but become conductors at higher temperatures.

The physical properties of metals include luster, malleability, ductility, and conductivity. Metals vary in reactivity. The most reactive metals will react even with cold water while the least will not react even with acid. The ease and speed with which a metal reacts with another substance is called its **reactivity**.

The reactivity of metals can cause deterioration of materials. The gradual wearing away of a metal due to interaction with other substances is called **corrosion**. In Grade 7, you have seen what happens to metals when exposed to acids. You have seen that iron *corrodes* when exposed to commercial acetic acid (or vinegar) for a long period of time. In the next activity, you will observe more of this type of reaction using a stronger acid this time. Bear in mind that some acids such as hydrochloric acid (or muriatic acid) which you will use in this activity can cause serious burns. Be responsible and handle it safely. Moreover, you will notice that the reactivity of some commonly used metals with an acid differ among metals. This reaction also causes harmful effects. Find out practical methods to prevent this damaging type of reaction.

Activity 2

Metal… Metal: How reactive are you?

Objectives:

After performing this activity, you should be able to:

1. compare the relative reactivity of metals in acid solution
2. find ways of preventing corrosion due to the reactivity of metals

Materials Needed:

a piece of copper wire - 4 cm. long
a strip of aluminum – 4 x 1 cm. (Don't use the glossy aluminum)
a strip of zinc metal – 4 x 1 cm.
an iron nail – 1 inch long
40 mL (10 – 12 % HCl) commercially sold muriatic acid
4 clean glass bottles of the same size (gerber or sandwich spread bottles will do)
10 mL glass graduated cylinder
sand paper or steel wool

Procedure:

TAKE CARE!

Muriatic acid is corrosive to skin. If any acid accidentally spills on you, wash the affected area with tap water. Notify your teacher.

1. Get 4 clean glass bottles and using 10 mL graduated cylinder, pour 10 mL of muriatic acid into each bottle.

2. Prepare the iron nail, copper wire, strips of aluminum and zinc metals. Clean these metal samples by rubbing them with sand paper or steel wool.

3. Place the iron nail in one glass bottle containing muriatic acid (HCl) and observe.

4. Place a white sheet of paper behind the bottle. This will make it easier to observe any reaction to happen.

5. Observe for 3 minutes. Record all observed changes in the table below.

Table 1. Data for Activity 2

Metal	**Observable Reactions with Muriatic Acid (Check and describe the metal observed)**		
	Violent	*Slow*	*No Reaction*
iron			
copper			
aluminum			
zinc			

6. Repeat procedure numbers 3 to 5 using each of the remaining metals. Compare the results.

Q1. Which of these metals – Fe, Cu, Al and Zn – reacts with muriatic acid? Which did not react with muriatic acid?

7. Arrange the metals in the order of their decreasing reactivity.

8. A reaction does not always happen between a metal and a compound. In this case, the reaction of metals with acid, like HCl, produces bubbles of hydrogen and a colorless solution of the metal chloride. There is an existing definite order of reactivity existing among metals and hydrogen according to their ability to displace one another. This arrangement is called the metal reactivity series or **activity series of metals**. The activity series is an arrangement of metals according to decreasing order of reactivity, as shown below.

Table 2. The Activity Series of Metals

Element	**Symbol**	**Group No.**	
Potassium	K	1	Most reactive
Sodium	Na	1	
Lithium	Li	1	
Calcium	Ca	2	
Magnesium	Mg	2	
Aluminum	Al	3	
Zinc	Zn	Transition metal	Decreasing chemical reactivity
Iron	Fe	Transition metal	
Tin	Sn	4	
Lead	Pb	4	
[Hydrogen]	H	Non-metal	
Copper	Cu	Transition metal	
Silver	Ag	Transition metal	
Gold	Au	Transition metal	
Platinum	Pt	Transition metal	Least reactive

Q2. What is the position (with respect to hydrogen) in the activity series of the metals that reacted or unreacted with muriatic acid (HCl) in the activity?

9. Locate the positions in the periodic table of the following elements from the activity series (these are members of the representative block): potassium (K), sodium (Na), lithium (Li), calcium (Ca), magnesium (Mg), and aluminum (Al).

Q3. Potassium, sodium, lithium are metals belonging to Group 1. In this group, how does reactivity vary – increasing or decreasing from top to bottom in the periodic table?

Q4. Does the relative reactivity of calcium and magnesium follow this trend?

Q5. Sodium, magnesium and aluminum belong to Period 2. Does reactivity increase or decrease from left to right among elements in a period.

10. From your answer in Q3-Q5, make a generalization of the variation of the reactivity of metals for those belonging to a group and for those belonging to a period.

11. Refer to the table, *Activity Series of Metals*.

Q6. Which will be more reactive in the following pairs of metal in every case?
   a. Mg or Na with HCl
   b. Ag or Al with HCl
   c. Fe or Zn with $CuSO_4$

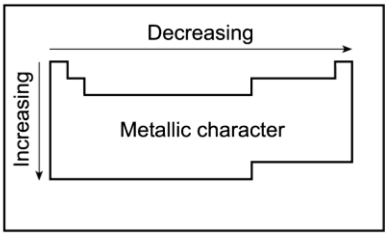
12. Think about the changes that you have observed around you, particularly those involving metals. You may also try to recall what you have done in Grade 7 when you placed an iron nail in a container of acetic acid.

Q7. What harmful change/s is/are brought about when a metal reacts or mixes with acids?

Q8. What are some ways of preventing corrosion of metals?

In the activity above, you have learned that the metals react differently with other substances. However, a general trend emerges as seen in the *Activity Series*, and evident in the periodic table as well. Refer to the periodic table, you will notice that the reactions get more vigorous as you go down the group and tend to decrease across a period. Therefore, with the help of the periodic table you may be able to predict the reactivities of metals.

With respect to position in the periodic table of the representative elements, metallic character increases from top to bottom and decreases from left to right; while nonmetallic character decreases from top to bottom and increases from left to right, as seen in the figure on the right.



Metallic property relates to how easy it is for an atom to lose an electron. On the other hand, nonmetallic property relates to how easy it is for an atom to gain an electron. Why do metals tend to lose electrons while nonmetals tend to gain electrons? In Module 2, you learned that the behavior of electrons is complicated to describe. However, we use a model of electronic structure which presents a picture where electrons occupy regions around the nucleus called **electron shells**. These are also called **energy levels** because each electron shell corresponds to a particular energy. Each electron shell can hold only a certain number of electrons. The way the electrons of an atom are distributed in the various energy levels or electron shells is called **electronic configuration**.

The lowest energy level is the one nearest to the nucleus. This is the energy level that electrons occupy first. It can accommodate a maximum of 2 electrons. If there are more than 2 electrons, they occupy the succeeding higher energy levels. The highest energy level that an electron occupies is referred to as the outermost shell or **valence shell**. The electrons in the valence shells are called **valence electrons.** These electrons are the ones involved in chemical reactions. The chemical properties of an element depend on the number of valence electrons.

The reactivity of metals is related to the ease with which they lose electrons in their valence shell. In Module 2 you learned that when an atom loses electrons, a cation is formed. In the next grade level, you will learn that some nonmetals, on the other hand, tend to gain electrons thus forming anions. The formation of ions among the elements results in the formation of many different compounds. In later levels, you will learn that some elements, instead of losing or gaining electrons, tend to share electrons with other atoms to form compounds. In all cases, it is the valence electrons which participate in the formation of these compounds.

PERIODIC TABLE

Key

atomic number
Symbol
name
atomic mass (gram/mol)

1	2	3	4	5	6	7	8	9
1 H hydrogen 1.008								
3 Li lithium 6.942	4 Be beryllium 9.012							
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			13 Al aluminium 26.98	14 Si silicon 28.09	15 P phosphorus 30.97	16 S sulfur 32.06	17 Cl chlorine 35.45	18 Ar argon 39.95
28 Ni nickel 58.70	29 Cu copper 63.54	30 Zn zinc 65.37	31 Ga gallium 69.72	32 Ge germanium 72.59	33 As arsenic 74.92	34 Se selenium 78.96	35 Br bromine 79.91	36 Kr krypton 83.80
46 Pd palladium 106.4	47 Ag silver 107.9	48 Cd cadmium 112.4	49 In indium 114.8	50 Sn tin 118.7	51 Sb antimony 121.8	52 Te tellurium 127.6	53 I iodine 126.9	54 Xe xenon 131.3
78 Pt platinum 195.1	79 Au gold 197.0	80 Hg mercury 200.6	81 Tl thallium 204.4	82 Pb lead 207.2	83 Bi bismuth 209.0	84 Po polonium (209)	85 At astatine (210)	86 Rn radon (222)
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Links

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http://www.google.com.ph/search?q=Mark+Buchanan+Periodic+Table

UNIT 4
Living Things and Their Environment

Suggested time allotment: 7 to 8 hours

Unit 4
MODULE
1

BIODIVERSITY

Overview

From Grades 3 to 7 you have studied some of the different organisms and their easily observable characteristics. You learned about those organisms that you find just around you and other places in the country. You were taught that organisms form the biotic component of an ecosystem. You were introduced to the cells that differ in plants and animals. In addition, you learned about organisms other than plants and animals. Some of these consist only of a single cell while others have many. You may also had a chance to look at organisms that are so small and can be seen only with the microscope.

This module will introduce you to the concept of **biodiversity,** specifically the variety of organisms living on Earth. This will discuss how they are classified and named. It will also show the similarities and differences of these organisms. It will describe the different groups to which these organisms belong. It will let you discover uses of some not just as food but also in medicine, agriculture, industries and the ecosystems where they are present. In addition, you will know about the harmful effects of some to other organisms.

The module will further show you the advantages of high biodiversity over low biodiversity. It will also help you recognize the value of biodiversity in your community**.** Most importantly, this hopes to encourage you to start or continue protecting and conserving your community's biodiversity for future generations.

Why is biodiversity important?

What human activities destroy or endanger the existence of rare and economically important species?

What human activities help protect and conserve rare and economically important species?

Levels of Biodiversity

Biodiversity is coined from the words, biological diversity. Usually, scientists would refer to three levels of biodiversity namely: different kinds of organisms (**species diversity**), genetic information that organisms contain (**genetic diversity**) and different kinds of places where organisms live and the interconnections that bind these organisms together (**ecosystem diversity**). If you recall, you have learned about ecosystem diversity in the lower grades. You will know more about genetic diversity in Grade 9.

Species diversity consists of the large number and all different kinds, shapes, colors and sizes of organisms that inhabit the Earth. It includes the smallest and the simplest bacterium (pl. bacteria) to the complex, bigger, brightly colored flower or fish. Add to this the carabao, the tallest acacia, the biggest elephant and a human like you. These organisms are found in various places from the soil, to the rivers, oceans, forests, salty or hot places, in short in every corner of the Earth. Some of them even live in your body. At present, more than a million organisms have been identified and named while many more are being discovered every year. Just recently, foreign and local researchers have found that diversity of reptiles and amphibians in the Northern Philippines is even greater than what has been known and identified.

If there are a lot more of the organisms in the world than you can count, how will you be able to know about them? Does an organism you see in your place, for example, have the same name in another place? Do organisms have to be classified? Why? Try the following activity.

Activity 1
What's in a name?

Objectives:

After performing this activity, you should be able to:

1. give the names of organisms as they are known in your community
2. recognize the need to have a system of classifying and naming organisms.

Materials Needed:

pictures of organisms
pencil or ballpen
sheet of paper

Procedure:

1. Get pictures of organisms from your teacher.

2. With your group, discuss how each of these organisms is called in your community. Accept any name which your groupmates will give for an organism. If you know other names by which an organism is called in another place, include them. Write these on the sheet of paper.

3. Be ready when your teacher asks you to present your work to the class. Take note of how the other groups named each of the organisms shown.

Q1. Are there organisms that others gave the same name to as your group did? Give examples.

Q2. Are there organisms that others gave a different name to as your group did? What are these organisms?

Q3. What can you say about your knowledge of the organisms before the other groups' presentations and the teacher's discussion?

Classifying and Naming Organisms

For organisms to be studied and information about them shared to those who need it, scientists grouped them into meaningful classifications. The different groups are ranked from the largest to the smallest groups. Large groups include many organisms with few similarities. Small groups include few organisms having more similarities. Organisms which have more similarities would then, be closely related than those which have less similarities. These classifications or categories consist of the **domain, kingdom, phylum, class, order, family, genus and species**.

The domain is the largest category into which organisms have been classified. This is followed by the kingdom category subdivided into various phyla (sing. phylum). A phylum consists of different classes, each class with several orders, an order with different families. Families consist of several genera (sing. genus) and each genus comprise the smallest group of various species.

A species is a group of similar organisms and capable of reproducing their own kind. This means only members of the same species can mate and produce fertile offspring. The dog, waling-waling (an orchid), milkfish (local name, *bangus*), rice plant and humans like you are examples of a species.

With the information available about organisms from the early studies to the present, scientists came up with the **three-domain system** of classification. Before, organisms were only grouped into **eukaryotes** and **prokaryotes**. Remember in your previous year, you knew about the nucleus in cells that contain DNA in chromosomes having a role in heredity. In eukaryotes, these materials are enclosed in a membrane while in prokaryotes they are not. Most prokaryotes are tiny and unicellular, thus, are referred to as **microorganisms**. A lot of eukaryotes are multicellular, thus, are larger in size because of the greater number of cells their bodies contain.

Recently, prokaryotes have been divided into two domains, namely: **Archaea** and **Bacteria**. The eukaryote group was retained and now consists the third domain (**Eukarya**) that includes protists, fungi, plants and animals. Table 1 shows an example of how organisms are classified.

Table 1. Sample classification of organisms

Category	Domesticated Cat	Dog	Bangus	Wolf	Lion
Kingdom	Animalia	Animalia	Animalia	Animalia	Animalia
Phylum	Chordata	Chordata	Chordata	Chordata	Chordata
Class	Mammalia	Mammalia	Actinopterygii	Mammalia	Mammalia
Order	Carnivora	Carnivora	Gonorynchiformis	Carnivora	Carnivora
Family	Felidae	Canidae	Chanidae	Canidae	Felidae
Genus	Felis	Canis	Chanos	Canis	Panthera
Species	*catus*	*familiaris*	*chanos*	*lupus*	*leo*

Q4. Which organisms in Table 1 are similar up to the Order category?

Q5. Which organisms are most closely related? Why do you say so?

Q6. Can a dog and a wolf produce fertile offspring? Explain your answer.

Recall in Activity 1 that local and common names created confusion. So, organisms also need be to given names for easier filing of information and reference by people. How are organisms named?

Q7. Examine the row for species in Table 1. What have you noticed?

For any organism identified, a **Scientific Name** is given. In this way, every scientist and other people from different places would use the same name for the same organism. This is what you see in the species row for each of the organisms. You must have observed that a scientific name consist of two names.

Q8. What does the first one refer to in the table? What about the second name?

This way of naming organisms is referred to as the **binomial system of classification**. Also take note that scientific names are in the Latin language and are italicized.

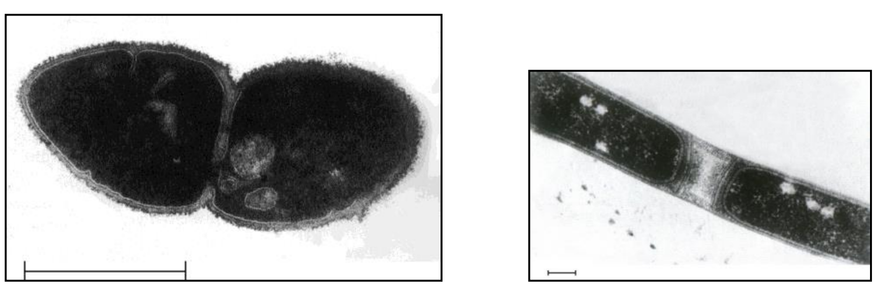
You should know, however, that researchers may differ in classifying organisms. It is important to bear in my mind that with further researches and discoveries this system of classification may change as more information are gathered about organisms found all over the Earth.

Early studies of organisms resulted to only the two-kingdom classification system. Later, with the invention of the microscope and with more evidences gathered about different forms of life, various scientists proposed three, to four, then, five and later to six or even eight-kingdom classification. Here, the six-kingdom classification will be used namely: Archaebacteria, Eubacteria, Protist, Fungi, Plant, and Animal kingdoms.

Archaea Domain: Kingdom Archaebacteria

Organisms that belong to this kingdom are all microscopic. They live in various places, some even in the most severe environments. **Methanogens**, **halophiles** and **thermophiles** are examples of archaebacteria.

Do you know that methanogens can survive in places where there is no oxygen? Some members of this group inhabit digestive tracts of animals and ponds where animal, human and domestic wastes are treated (Figure 1). Methanogens are also present on bottoms of lakes, swamps and rice fields. An important characteristic of this group is they produce **methane** gas. If you live near rice paddies and swamps the bubbles that pop at the water surface is methane.



(a) (b)

(Source: Philippines. Department of Education. (2009). Science and Technology II. Textbook (Rev. ed.). Pasig City: Instructional Materials Development Corporation. p.243.)

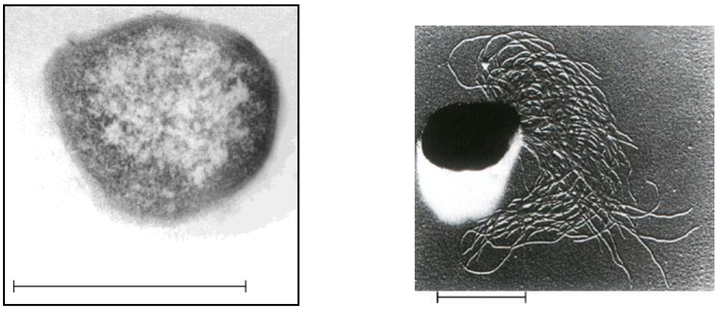
Figure 1. Examples of methanogens. (a) Methanobacterium ruminatum, from cow stomach undergoing division, and (b) Methanospirillum hungatei, from waste treatment ponds (bar scale = 1 μm). The symbol μm means micrometer. 1 μm is equal to 0.001 m.

Methane is utilized as **biogas**, a cheap alternative source of energy. There are already communities and industries which obtain energy for their lighting and cooking fuel needs from the biogas technology.

If you live in areas which make salt, have you observed the orange or yellow color in salt ponds? This is due to the presence of halophiles. These archaebacteria are adapted to very salty environments. Examples are *Haloccocus dombrowski* and *Halobacterium salinarum.*

Q9. Read about the Dead Sea and the Great Salt Lake of Utah, USA. What do these have in common?

Figure 2 below are examples of thermophiles. This group of archaebacteria can live in places with high temperature. These areas include volcanic hot springs with temperatures from 80 to 110°C. They also inhabit the small deep sea openings where hot water with temperatures higher than 250°C come out. Thermophiles turn hydrogen sulfide (H_2S) released from these openings to food for other organisms and in turn are provided essential nutrients by the former.



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(Source: Philippines. Department of Education. (2009). Science and Technology II. Textbook (Rev. ed.). Pasig City: Instructional Materials Development Corporation. p.242).

Figure 2. Electron micrographs of thermophiles (a) Pyrodictium occcultum and b) Pyrococcus furiosus (bar scale = 10 μm). 10 μm = 0.01 mm.

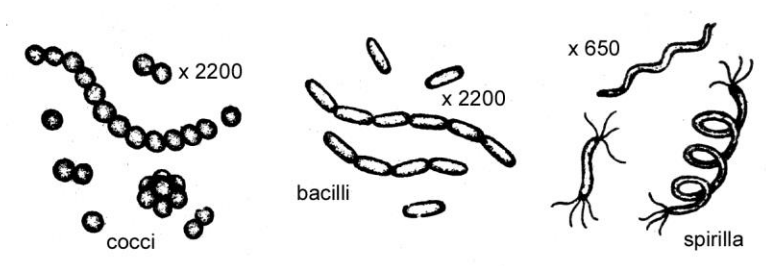
Some members of archaebacteria also survive acidic and even cold environments.

Bacteria Domain: Kingdom Eubacteria

Members of eubacteria are unicellular and microscopic. They are referred to as the true bacteria and are usually called the “bacteria” group. Their cell walls are made of peptidoglycan, a carbohydrate.

Q10. What comes into your mind when you hear the word bacteria?

Bacteria consist of a very diverse group. They have varied shapes (Figure 3). They can be found in almost all kinds of places, in soil, water and air. Some are present in raw or spoiled food; others live in or on other organisms including your body. You must have known that they also cause disease and harm to other organisms. But most importantly, bacteria have a variety of uses for the environment and for humans.



(Adapted from: Philippines. Department of Education. (2009). Science and Technology II. Textbook (Rev. ed.). Pasig City: Instructional Materials Development Corporation. p.246).

Figure 3. Basic shapes of bacteria.

Q11. Study Figure 3. Describe cocci, bacilli, and spirilla.

Bacteria are classified according to shape as shown in Figure 3. Also notice that cocci (sing. coccus), are differently arranged. They can form pairs (diplococcus), chains (streptococcus), or clusters (staphylococcus). Bacilli can also occur in chains (streptobacillus).

Most of the time, you probably think of diseases when bacteria which you refer to as “germs” in the early grades is mentioned.

Are you aware that when your oil glands swell and result to pimples, they are infected with the bacterium *Propionibacterium acnes*? A lot of human diseases are caused by bacteria. Tuberculosis, one common disease in the Philippines, is caused by bacterium *Mycobacterium tuberculosis*.

Have you heard about the rise of leptospirosis cases in the recently flooded areas in a number of places in the country? Leptospirosis is a bacterial infection due to exposure to the spirochete bacterium, *Leptospira interrogans*. These bacteria are present in the urine and tissues of cattle, pigs, horses, dogs, rats, and wild animals. It has been found out that the largest number of leptospira bacteria are in the urine of rats. Anybody can be infected through contact with water, soil, food and vegetables that are contaminated with urine of these animals. The bacteria enter the body through cuts in the skin or surfaces of the eyes or nose. It is important for you to know that the disease is preventable and treatable with antibiotics.

Q12. Can you think of ways by which you can avoid leptospirosis?

Bacteria also cause diseases in animals. *Bacillus anthracis* is responsible for the disease called anthrax. The bacterium is found in the soil and can survive for many years. The disease affects animals like cows and carabaos but can be transmitted to humans. Skin anthrax occurs in the Philippines through contact with animal tissues or their products. Inhalation and intestinal anthrax caused by inhaling spores and eating of contaminated or undercooked meat, respectively, are more deadly. It is strongly advised to refrain from eating meat of dead animals suspected to have died of anthrax. In the early 2000's there was a worldwide threat of using anthrax spores to kill people in what is termed as "biological" warfare.

Q13. Who do you think are the people who are likely to be infected with anthrax?

Antiobiotics are substances that kill or inhibit disease-causing organisms. Do you know that certain bacteria are used to produce antibiotics? Streptomycin, an antibiotic used to treat tuberculosis and certain types of pneumonia is made by *Streptomyces griseus*. *Streptomyces venezuelae* on the other hand produces chloramphenicol used in killing bacteria that cause typhoid fever and skin infections.

Escherichia coli is naturally found in the large intestine of humans. It feeds on partially digested food moving from the stomach to the small intestines. These bacteria meanwhile provide the much needed vitamin B_{12} that otherwise the human body cannot produce. *E. coli* however, once present in other areas in the body can produce poisons causing diarrhea or kidney damage and even death.

Do you know that many of these bacteria are also involved in making some of the foods or drink you like?

Some bacteria convert cheap materials into useful products such as food. Examples are *Lactobacilli bulgaricus* and *Streptococcus thermophilus* of the lactic acid bacteria group. These are specifically involved in making sour milk or yogurt. Yogurt is made by adding a culture of *Lactobacillus bulgaricus* present in the starter to skimmed milk powder. Lactase in the bacteria changes the milk sugar into lactic acid. When this occurs, proteins in milk curdle which gives yogurt its semi-liquid texture. Be familiar with these bacteria by doing the following activity.

Activity 2
How do bacteria in yogurt look like?

Objectives:

After performing this activity, you should be able to:

1. identify bacteria present in fermented food or drink
2. describe bacteria observed under the microscope
3. explain the use of bacteria in food or drink making

Materials Needed:

2 droppers	diluted yogurt
coverslip	glass slide
microscope	methylene blue

Procedure:

1. Place a drop of diluted yogurt on a slide.

2. Add a drop of methylene blue and cover with a cover slip.

Q14. What is the purpose of adding methylene blue to the specimen?

TAKE CARE!

Follow precautionary measures in handling the microscope.

3. Observe under the LPO and HPO of the microscope.

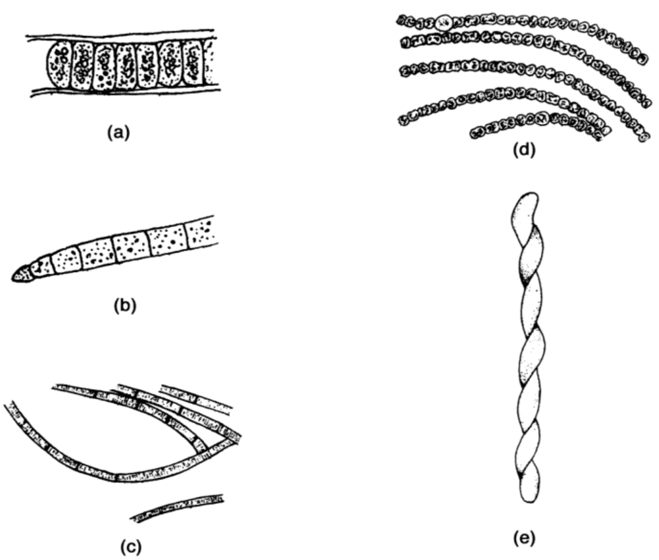
Q15. Describe what you see under the HPO.

Q16. Which are *Lactobacillus* bacteria in yogurt? Which are *Streptoccus* bacteria?

Q17. What are your reasons for saying so?

Have you heard about "oil-eating" bacteria? Some members of eubacteria are able to break down or remove pollutants through the process of **bioremediation**. Scientists at University of the Philippines-Diliman's Molecular Microbiology Laboratory have identified a number of bacteria which can help solve the problem of oil spills in oceans and seas through this technology. These are *Pseudomonas aeruginosa, Acinetobacter baumanii, Paenibacillus thiaminolyticus, Bordetella bronchiseptica and Lysinibacillus sphaericus.*

Another group of bacteria (Figure 4), the **cyanobacteria** are plantlike because they have chlorophyll-containing cells. Most of them are single-celled, some form filaments, while others form spores. Cyanobacteria grow in ditches, *esteros*, or in moist places like gardens and sidewalls where light is present. In Northern Luzon people *eat raw Tab-tab* (*Nostoc*) as salad. *Spirulina* cells are rich in protein, thus, have been grown to produce Single Cell Protein (SCP). It is used as swine and cattle feed and is also recommended as food for humans.



(Source: Philippines. Department of Education. (2009). Science and Technology II. Textbook (Rev. ed.). Pasig City: Instructional Materials Development Corporation. p.249.

Figure 4. Examples of cyanobacteria are (a) Lyngbya, (b) Microcoleus, (c) Oscillatoria, (d) Nostoc, and (e) Spirulina.

Anabaena azollae, another cyanobacterium is important in agriculture. It converts nitrogen in air into compounds usable by plants for growth and development. The same is being done by the *Rhizobium* group of bacteria. They are present in the root nodules of legumes.

Q18. What is the advantage of planting legumes together with other crops?

Certain bacteria, like *Bacillus thuringiensis*, have been developed into a microbial pesticide. It is used to control pests and and insects carrying disease-causing organisms.

Protists

Earlier you were introduced to protists. Are they prokaryotes or eukaryotes? What can you remember from Grade 7 about algae? How were they classified?

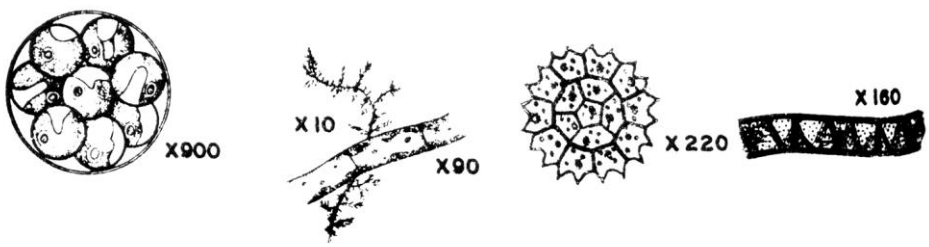
Members of Kingdom Protista come from unrelated ancestors. This grouping is referred to by biologists as an artificial grouping. The inclusion of the large number of unicellular organisms under this kingdom is just for convenience.

Protists differ in size, movement and method of obtaining energy. Though most of protists are microscopic, some can grow to as high as several meters.

In terms of method in obtaining energy, protists are classified into three groups. **Phototrophs** produce their own food. **Heterotrophs** feed on other organisms. This group is also divided into a group with no permanent part for movement, those with cilia, and those with limited movement. Others which are nonmotile and form spores belong to the **sporozoan** group. Members of this group are all parasitic.

Phototrophs are like plants in that they have chlorophyll. This group includes the **algae**, **dinoflagellates**, and **euglenoids**.

Algae may be green, golden, brown or red. The chlorophyll in green algae is not masked in contrast to the other members of the group. The carbohydrate that green algae produce is stored as starch. They grow on wet, humid rocks or bark of trees, in non-flowing canals, in seas, freshwater bodies and even polluted waterways. **Green algae** differ in size and shape. Some are unicellular; others form colonies, sheets, filaments, tubes and ribbons (Figure 5). Some green algae are edible. The marine green alga *Caulerpa lentillifera* is eaten fresh as salad.



(a) (b) (c) (d)

(Source: Philippines. Department of Education. (2009). Science and Technology II. Textbook (Rev. ed.). Pasig City: Instructional Materials Development Corporation. p.255).

Figure 5. Examples of green algae (a) ***Chlorella****, (b)* ***Draparnaldia****, (c) colonial* ***Pediastrum****, and (d) filamentous* ***Spirogyra***

Golden algae (Figure 6) cells also contain chlorophyll but is masked by yellow pigments. Members of this group are mostly microscopic. They store food in the form of leucosin oil or chrysolaminarin.

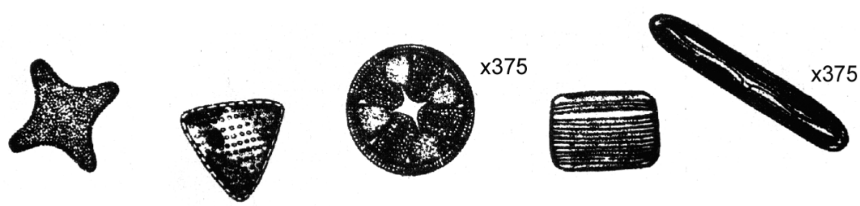


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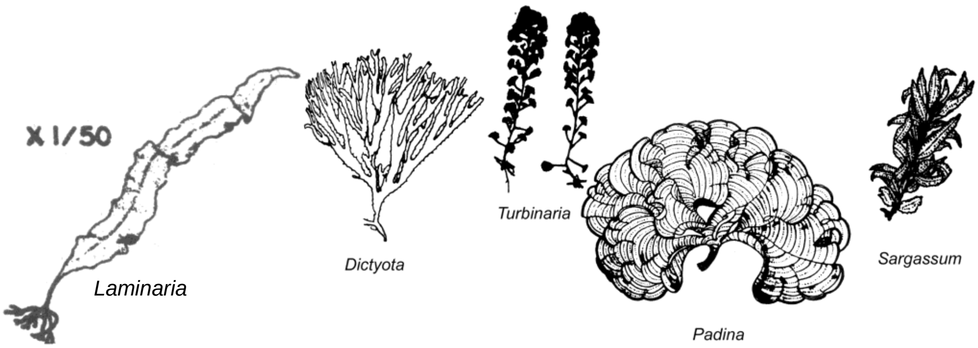
Figure 6. Diversity in shape of diatoms, a golden algae.

In one of your trips to the seashore, did you notice something like one of those shown in Figure 7? If your answer is yes, you have seen **brown algae**! Most members of this group are marine so you can see them just lying around on the beach. Brown pigments mask their chlorophyll.



(Source: Philippines. Department of Education. (2009). Science and Technology II. Textbook (Rev. ed.). Pasig City: Instructional Materials Development Corporation. p.257).

Figure 7. Some common brown algae found in the marine waters of the Philippines

Brown algae are the largest of the algae species. Giant kelps, a member of this group can grow to more than 30 meters in length. This group of algae store carbohydrate in the form of laminarin.

Do you know that brown algae have something to do with your favorite ice cream or toothpaste? Some members of the group contain alginic acid used as an ingredient in making these two, including candy and cream cosmetics.

Leaflike and bubblelike structures called bladders are present in brown algae. They float near the water surface where light is present.

Q19. What is the importance of bladders in brown algae?

Have you heard eaten *gozo*? *Eucheuma muricatum* (Figure 8) or *kanot-kanot*, another name for gozo, is a member of the **red algae** group. The group differs from the rest of the algae by storing food in the form of floridean starch. As their name suggests, red pigments mask their chlorophyll.

Eucheuma muricatum ***Gracilaria salicornia***

(Source: Philippines. Department of Education. (2009). Science and Technology II. Textbook (Rev. ed.). Pasig City: Instructional Materials Development Corporation. p.257).

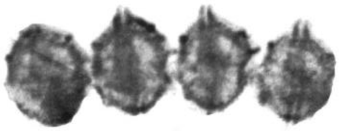
Figure 8. Examples of red algae.

Red algae can change color depending on whether they are exposed or hidden from light. When they are exposed to light, they are bright green in color. If they grow without much light, they are colored red. Members of the group consist of both microscopic and large multicellular organisms. Most of them are found in marine waters.

There are species in the group that help form coral reefs because of their ability to produce calcium carbonate. Economically, *E. muricatum* is useful being a source of agar and carageenan. If you are fond of eating gulaman, note that it comes from agar. *Eucheuma* farming has become a source of livelihood in certain areas in Central Visayas and Mindanao. Likewise, *Gracilaria salicornia* (Figure 8) is an agar source and edible too.

Q20. Why is light important to algae?

Most members of dinoflagellates live in oceans and seas. They are mostly unicellular. Some occur as single organisms, while others form colonies. An important dinoflagellate to know is *Pyrodinium bahamense* var. *compressum* (Figure 9). They are the ones that cause “red tide” when present in large numbers. During red tide, people should not eat clams and mussels in the affected areas. This is because these organisms might have fed on the dinoflagellates which produce toxins and cause paralysis of the diaphragm that can lead to death.



(Adapted from: Philippines. Department of Education. (2009). Science and Technology II. Textbook (Rev. ed.). Pasig City: Instructional Materials Development Corporation. p.255).

Figure 9. Pyrodinium bahamense var. *compressum, the red-tide causing dinoflagellate.*

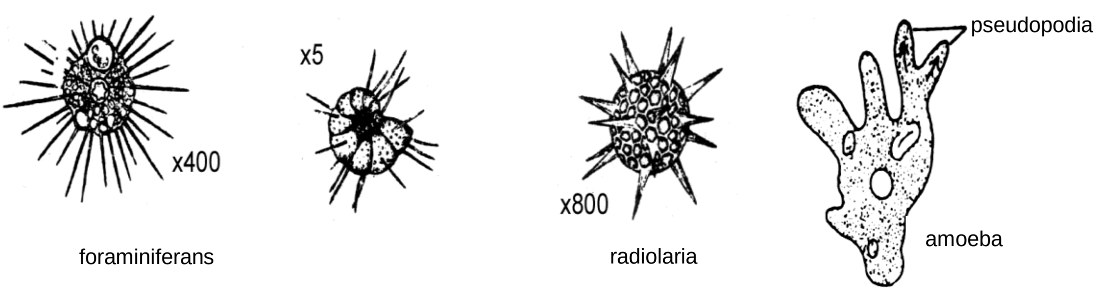
Q21. What is the danger of eating clams when red tide occurs?

The euglenoids are microscopic and unicellular. *Euglena* belongs to this group. It lives in freshwater bodies. Organisms of this group have a whiplike flagellum for movement. Some euglenoids have chlorophyll.

Euglena has an interesting characteristic of getting food. When light is available to, it makes food utilizing chlorophyll. In the absence of light, it absorbs nutrients from dead organic matter.

Heterotrophs with no permanent structure for movement include the **radiolarians**, **foraminiferans** and **amoeba** (Figure 10). They move by means of the pseudopods or pseudopodia. Notice the extensions at the sides of these organisms. These temporary extensions are formed when changes in the cytoplasmic concentration occur within the cell. This change causes the cell membrane to contract and enable the organism to make a creeping movement. Pseudopods may form as they are needed.

Q22. Compare pseudopods of foraminiferans, radiolarians and amoeba.



(Source: Philippines. Department of Education. (2009). Science and Technology II. Textbook (Rev. ed.). Pasig City: Instructional Materials Development Corporation. p.259).

Figure10. Examples of heterotrophs using pseudopodia for movement.

Entamoeba histolytica is a harmful species of amoeba living in freshwater bodies. If present in underground water, it can contaminate drinking water. Once this happens, the gastrointestinal tract is infected causing amoebiasis. If the protist invades the intestinal lining it leads to amoebic dysentery. Proper sanitation must be practiced to ensure clean and safe drinking water.

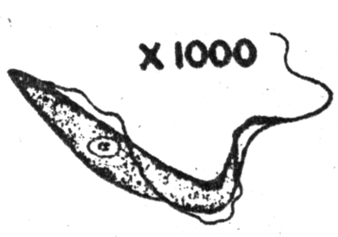
Another heterotroph, the **paramecium**, moves using the cilia attached to parts or all over its body. The ciliate group are free-living and present in both fresh and salt water. They also use the cilia to get food. Other examples are the ***Didinium*** and ***Vorticella***.

Slime and **water molds** are motile in a certain stage in their life cycles. Thus, they are considered to be heterotrophs with limited movements. Slime molds are usually the colored yellow, orange, or whitish growths that you may see on damp rotting logs. They feed on bacteria and decaying plant material in the same manner as an amoeba does. Water molds are white cottony growths on dead fish or plant parts that you might see floating in water. Certain species of water molds are parasitic on corn, grapes cabbage and many other important crops.

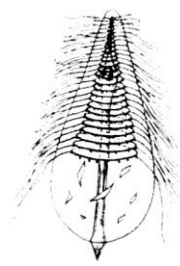
Members of the sporozoan group as mentioned earlier cannot move on their own. They may be free-living and parasitic. Some like four species of *Plasmodium* are harmful for they cause malaria, a serious disease in humans. This malaria-causing sporozoan is transmitted to humans by *Anopheles* mosquito. In the Philippines malaria is still constantly present in certain areas.

Another group of heterotrophs include the flagellates. They are unicellular and they use one or many of their threadlike flagella to move. Some of them exist as single organisms though others form colonies. There are parasitic and free-living flagellates. Two important species to study are *Giardia lamblia* and *Trypanosoma gambiense* (Figure 11a) because they affect humans. *G. lamblia* cause severe diarrhea, while *T. Gambiense* is responsible for Gambian sleeping sickness.

Trichonympha (Figure 11b) is beneficial to other organisms. It lives in the intestine of termites. Since termites cannot digest the wood that they eat, *Trichonympha* do it for them. Termites in turn give them a home and food to eat.



Trypanosoma
(a)



Trichonympha
(b)

(Source: Philippines. Department of Education. (2009). Science and Technology II. Textbook (Rev. ed.). Pasig City: Instructional Materials Development Corporation. p.259).

Figure 11. (a) Harmful and (b) beneficial flagellates

Q23. Give at least five uses of protists.

Fungi

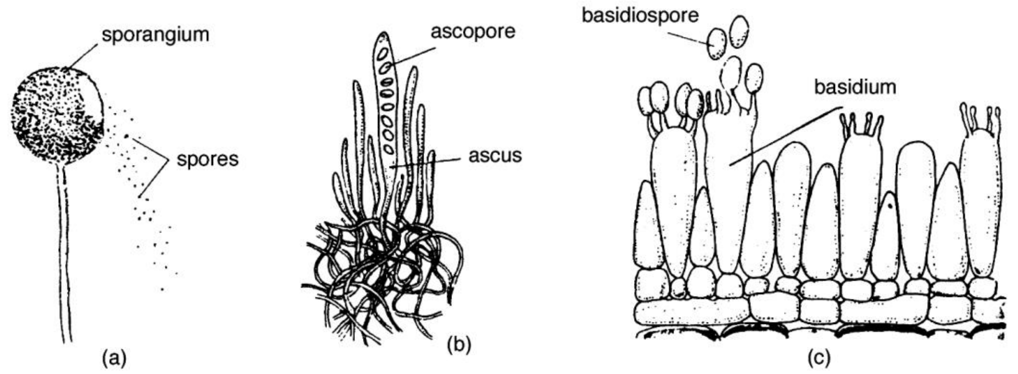
You must have seen the orange colored growth on spoiled corn, the gray to black or white spots on a three-day old bread left in a warm and humid or moist place. Or the *kabuti*, that your father gathered from the woods and yeast used in making bread. All these are fungi.

You first encountered the eukaryotic fungi in Grade 7. You have also learned that they have no chlorophyll thus, cannot produce their own food. Some are parasites, because they survive by living on a host organism. Others feed on decaying matter and are called **saprophytes**. Fungi also have cell walls but are made up of chitin.

Fungi undergo asexual reproduction by forming buds and many spores. Actually, the black thing you see in fungi are spores in large numbers. These spores are abundant in the environment as they are carried easily by wind, water, animals, or humans. When spores land in areas suitable for their growth, new fungus develops.

Fungal bodies consist of **hyphae** with rootlike **rhizoids** that attach them to the substrate on which they grow. Hyphae absorb and provide nutrients to the fungi by extending downward into the substrate. Fungi also reproduce sexually when male and female hyphae join together.

Fruiting structures extend upward where spores are produced. Fungi are classified according to the kind of fruiting structures they form (Figure12). In bread mold *Rhizopus*, spores are produced in the sporangium.



(Source: Philippines. Department of Education. (2009). Science and Technology II. Textbook (Rev. ed.). Pasig City: Instructional Materials Development Corporation. p.264).

Figure 12. Differences in the fruiting structures of three groups of fungi. (a) occurs in bread mold, (b) in yeasts and (c) in mushrooms.

Q24. Where are spores of yeasts produced? How are yeast spores called?

Q25. Where are mushroom spores produced?

Q26. What is the advantage of the large numbers of spores produced by fungi?

Examples of fungi used as food are *Volvariella* sp. and *Pleurotus sajor-caju* (oyster mushroom). Others utilized in soy sauce making include the yeast, *Saccharomyces rouxii* and the mold, *Aspergillus oryzae*. Yeast is an ingredient in making bread.

Fungi are involved in decomposing organic materials. Decomposition is made faster using *Trichoderma harzianum*. An important mold to mention is *Penicillium notatum*. It is used in making penicillin, a drug that kills disease-causing bacteria.

Some fungal species however, can be harmful to other organisms and humans. The mold *Aspergillus flavus* produces *aflatoxin*, a poisonous substance. If large amounts of aflatoxin in moldy corn, garlic or peanuts are ingested, both poultry and humans can be poisoned. The parasitic fungi *Trichophyton mentagrophytes* and *T. rubrum,* cause athlete's foot. *T. rubrum* can also cause ringworm.

Q27. From what you know and have observed about fungi, in what conditions do they grow?

The Plant Kingdom

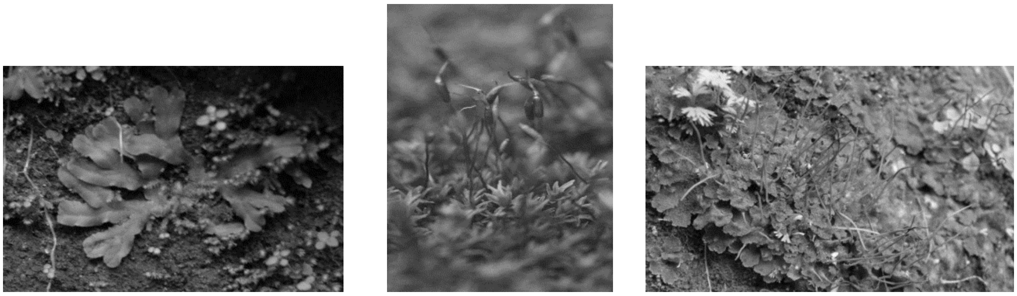
Recall what you know about plant cells. Do they have chloroplasts? What are their cell walls made of?

You knew earlier that plants belong to the eukaryote group. They are multicellular and because they have chlorophyll, they can make their own food. Plants consist of two big groups: those which do not have tissues to transport water and food (**nonvascular**) and those that have this transport system (**vascular**).

Nonvascular Plants

Have you noticed green patches attached to stones or cement walls especially during the rainy season or in moist, wet and shady areas?

Liverworts, mosses and hornworts (Figure 13) are nonvascular plants. They are attached to the places where they live by means of their root-like **rhizoids**. These rhizoids absorb water and nutrients instead of true roots. They also do not have true stems and leaves so they grow very close to damp grounds, stone walls or tree trunks.



Photos courtesy of Addie A. Saliva

(a) (b) (c)

Figure 13. Example of nonvascular plants (a) liverworts, (b) mosses, and (c) hornworts.

Q28. How do liverworts, mosses and hornworts differ in appearance?

When nonvascular plants mature, they also form different reproductive structures. Liverworts develop “umbrella-like” structures that produce eggs and sperms. Notice in Figure 13b the **capsules** at the tip of thin stalks in mosses. These capsules contain the spores. In hornworts, you see them as thin “thorn-like” structures.

Nonvascular plants may seem very small but they play an important role in the environment. They provide oxygen to many organisms. Their “carpetlike” growth covering large areas in hilly grounds prevent erosion and increase the capacity of soil to hold water. Dried ***Sphagnum*** or peat moss is used to wrap plants and breakable items during transport. Gardeners use them to retain more water in the soil for important crops. Old, dead sphagnum form thick deposits called **peat**, which is used as fuel in some places.

Q29. Why do you think nonvascular plants cannot grow very large or tall?

Vascular Plants

From studying water-dwelling organisms, you will now deal with ferns which thrive on land with true roots, stems and leaves. Ferns also reproduce by spores. More than 900 species of ferns can be found in moist, shaded and mountainous areas in the country. They exhibit diversity in size from a few millimeters to about 12 meters. Some ferns still inhabit freshwaters (Figure 14b), while others grow on tree trunks. The *Anabaena* cyanobacterium you studied earlier are present in the underside of azolla, a water fern.

Q30. Examine Figure 14a. Can you explain how it earned its name?

Have you heard of tree ferns (Figure 14c)? At first glance, you may think it is a tree with a sturdy trunk. You should know that they are not strong as woody plants.

Photo by: Alvin J. Encarnacion

Giant fern, *Angiopteris* sp.

(a)

Photo courtesy of Michael Anthony B. Mantala

Salvinia sp.

(b)

Photo by: Karina Luth Discaya

Cyathea sp. (tree fern)

(c)

Figure 14. Examples of Philippine ferns (a) Giant fern, (b) water fern and (c) tree fern.

Q31. How will *Azolla* help rice if they are grown together in fields?

With the fern's ability to make food, they too provide other organisms with food and oxygen. You are also familiar with the use of ferns as plant decoration. Some Philippine handicrafts are made from fern fibers like *nito*.

Q32. Give other uses of ferns in your locality.

Gymnosperms

Seed plants consist of those which bear seeds contained in cones and those inside a protective layer of tissue. Plants whose seeds are borne in cones (Figure 15a) are called gymnosperms. Examples of gymnosperms are the conifers, cycads, ginkgoes, and gnetophytes. Many conifers like pine trees grow in cold countries and in elevated places in warmer climates. They are woody trees and have tough needle-like leaves.

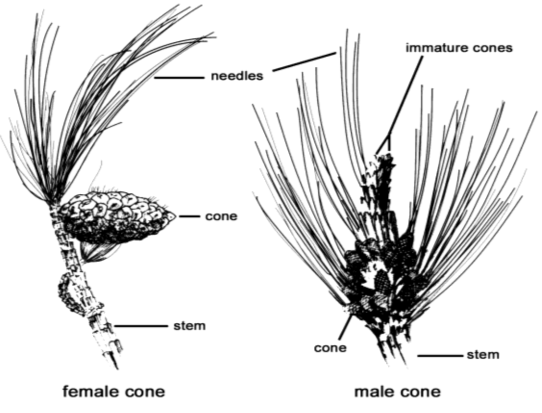


Photo by Rodolfo S. Treyes

(Source: Philippines. Department of Education. (2009). Science and Technology II. Textbook (Rev. ed.). Pasig City: Instructional Materials Development Corporation. p.264).

(a) (b)

Figure 15. (a) Benguet pine cones and (b) a Ginkgo biloba tree growing in Tokyo, Japan.

Q33. Where in the Philippines would pine trees likely grow?

Cycads are short, palm-like plant growing in tropical and subtropical areas. In the Philippines they are seen in well-landscaped hotels and parks. Gnetopytes are represented by Welwitschia which can be found in Namibia, Southwestern Africa.

Gymnosperms are sources of quality wood for making plywood and furniture. They also supply pulp to paper-producing factories. Other species provide resin, used in making perfumes and varnishes. Pine cones are popular Christmas decoration items.

Q34. How would uncontrolled cutting of pine trees, for example, affect the forest ecosystem?

Angiosperms

You are most familiar with members of this group as you may have played with their flowers even at an early age. In the earlier grades, you have learned how varied they are in terms of parts and habitat. You also studied about what parts are involved in reproduction and ways by which they reproduce. They are also called flowering plants since flowers, as well as fruits, are involved in their reproduction and development.

Angiosperms can be classified according to their lifespan. Annuals live for a year or one growing season and die like rice and corn. Biennials develop roots, stems and leaves during the first year, produce seeds on the second year, then die. Perennials live for many years, usually producing woody stems like *tsitsirika*, bamboo, and trees.

Leaves of angiosperms also differ in their arrangement in the stem. Study Figure 16.

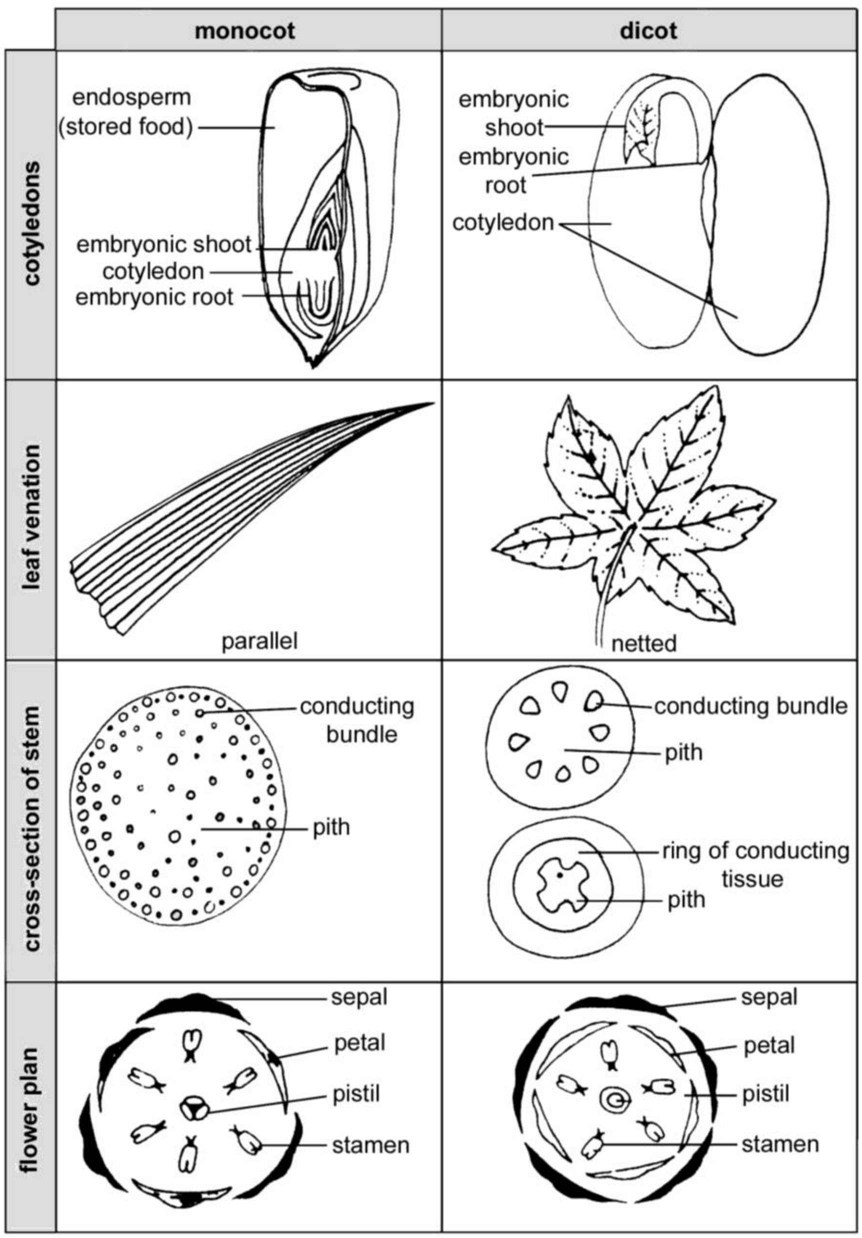
*Coffea arabica (*coffee)   *Allium sativum* (garlic)   *Anacardium occidentale* (cashew)

(Source: Philippines. Department of Education. (2009). Science and Technology II. Textbook (Rev. ed.). Pasig City: Instructional Materials Development Corporation. p.276).

Figure 16. Differences in arrangement of leaves in plant stems

Q35. Which plant leaves are arranged alternately, radially and opposite each other?

Flowering plants are also classified as to the number of cotyledons present in their seeds. Monocotyledons or monocots have only one cotyledon present, while dicotyledons or dicots have two. Coconut and grasses are examples of monocots. *Gumamela* and mango are dicots. Other differences among the two are exhibited in characteristics of some of their parts as shown in Figure 17.



(Source: Philippines. Department of Education. (2009). Science and Technology II. Textbook (Rev. ed.). Pasig City: Instructional Materials Development Corporation. p.276).

Figure 17. Characteristics of monocots and dicots

Q36. In terms of leaf venation, is santan a dicot or a monocot?

Q37. How about bamboo?

Recall the structure of the flower you studied in Grade 7. Angiosperms can also be differentiated by means of their flower parts. A flower may have both petals and sepals or may have sepals or petals only. Others have stamens, petals and sepals attached to the ovary. Some have their petals separated, others are united. You can observe several flowers from different plants and you may see other differences or similarities among them.

Importance of Angiosperms

Look around you. Think of what you have eaten or what you have used earlier. Were there any from this group of plants mentioned that you have eaten, or in any way used?

Angiosperms of importance worth mentioning are Filipinos' staple food: rice for most of us, corn in some areas; vegetables like *camote* tops, *malunggay,* cabbage, carrots, *saluyot* and squash.

Q38. Make a list of the uses of coconut that you know.

Many of our agricultural products, both fresh and processed are exported. Examples are banana from Davao, mango from Guimaras, coffee from various provinces, pineapple from Bukidnon and tobacco from provinces in Northern Luzon. Furniture made from rattan are also sold to various countries abroad. Sugar cane from different provinces is also another grown for export.

Many angiosperms have been developed to prevent and cure some diseases. *Lagundi*, *sambong*, ampalaya, and *banaba* to name a few are now commercially available for specific ailments.

Q39. Describe how birds, butterflies and spiders benefit from members of the angiosperms.

Q40. What is the greatest contribution of plants to living things on Earth?

Harmful Plants

Some plants can be harmful to animals, humans, and even to other plants. Care must be taken that cows and other livestock should not graze in areas where sorghum grow. It is known to cause cyanide poisoning in livestock as young leaves contain a poisonous substance.

Jatropha curcas (tuba-tuba/tubang bakod) is popular due to its being an alternative source of bio-fuel. Although known to have medicinal properties, its seed is poisonous. The fruits which are usually eaten by children cause stomach pain, burning sensation in the throat and vomiting. *Manihot esculenta* (cassava) if boiled with its bark on it can be poisonous. The bark contains hydrocyanic acid. It is advised that during cooking, the pot cover should be removed for the cyanogas to escape. A word of caution: do not eat any part of a plant which you are not familiar with.

Echinochloa crus-galli (dawa-dawa) and *Digitaria sanguinalis* (saka-saka) are weeds which are alternative hosts to abaca and corn mosaic viruses.

Q41. What harm can weeds do to crops if they grow together?

The Animal Kingdom

What can you remember about the characteristics of animal cells? How do animals differ in size, shape or habitat? How do they respond to their environment?

Animals differ in size and shape. In Grade 7, you learned that small ones have few cells while big ones can have up to trillions! Some animals can live inside other animals. Others are found in fresh or marine waters and some in every habitat on land. They reproduce either sexually or asexually.

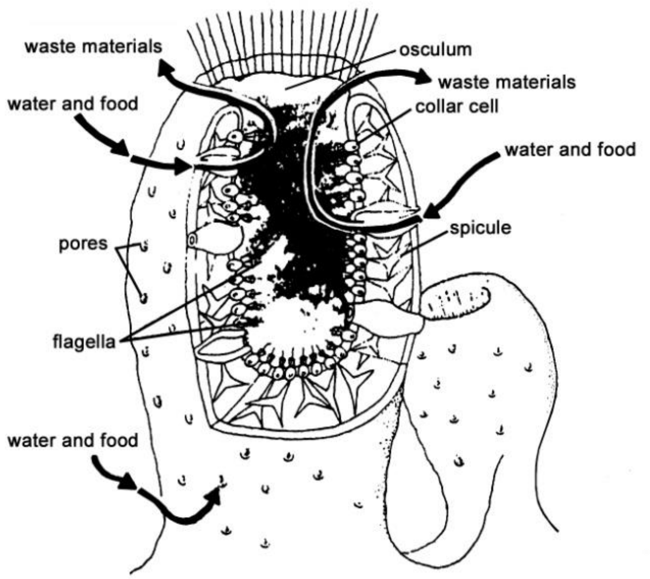
Despite their differences, animals share basic characteristics. By now you must have known that this group are eukaryotic and multicellular. Some get nourishment from other animals, others eat plants while others feed on protists. You knew that animal cells have no cell walls. But they have cells involved in movement though some species are nonmotile. Animals also have cells that transmit messages throughout their body.

Q42. In your observation, how are animals distinguished from the other groups as to their reaction to stimuli?

Animals consist of two major groups, the invertebrates and vertebrates. Invertebrates lack backbone which is present in vertebrates. In this section, you will discover the diverse characteristics, uses and roles in the environment of nine in about thirty five animal phyla.

Sponges

Sponges, the simplest animals, belong to Phylum Porifera. They live in shallow and deep oceans. The young of sponges are motile, while adults are attached to solid materials like rocks. The body of a hard sponge is supported by a "skeleton" called **spicules**, made of either glasslike silica or calcium carbonate. A network of protein fibers supports soft sponges. This is the one used for bathing and washing.



(Source: Philippines. Department of Education. (2009). Science and Technology II. Textbook (Rev. ed.). Pasig City: Instructional Materials Development Corporation. p.285).

Figure 18. Structure of a sponge showing how water and food and waste materials move in and out of its body, respectively.

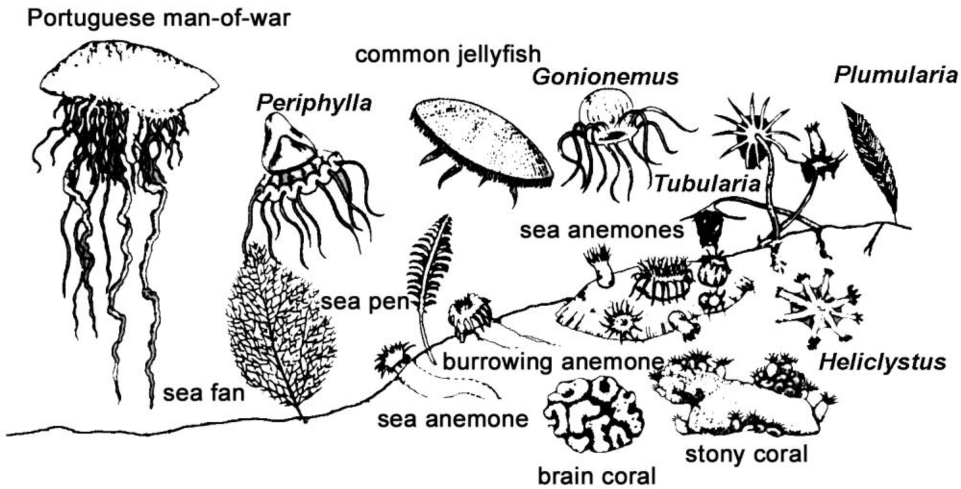
Water and food enter through the pores into the sponge body (Figure 18). Food is brought to the collar cells with the beating of flagella. Waste water and materials go out of the sponge through the **osculum**.

Cnidarians

Members of Phylum Cnidaria consist of animals whose tentacles contain stinging cells called **nematocysts**. These poison-filled structures are used for defense and to capture their prey or food. Once released, this can be painful and even fatal like an attack by jellyfishes.

Corals form colonies of various colors and secrete a hard skeleton. These accumulate to form coral reefs which are of great importance as they are one of the world’s most productive ecosystems. A coral reef is where fishes and other marine organisms breed. At present however, coral reefs are destroyed by pollution from oil spills and dynamite fishing. Add to these the silt and sediments that flow down from the mountains because of farming, mining and logging activities.

Hydra represent freshwater cnidarians. Other marine cnidarians are shown in Figure 19.



(Source: Philippines. Department of Education. (2009). Science and Technology II. Textbook (Rev. ed.). Pasig City: Instructional Materials Development Corporation. p.287).

Figure19. Variety in marine cnidarians.

Q43. Which cnidarians are attached? Which are free-swimming?

Flatworms

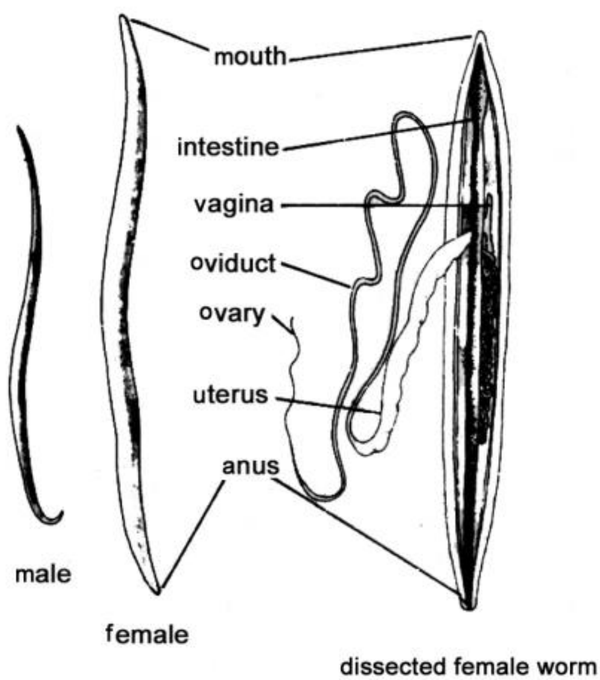
The flatworm group belongs to Phylum Platyheminthes (in Greek *platys* means flat, *helmins* means worm). As their name suggests, they are flat and ribbon-like organisms. Flatworms are found in freshwater, in wet places and marine waters. They include the free-living or nonparasitic worms, the parasitic flukes, and the tapeworm group. Planaria is an example of a free-living flatworm. It lives in moist surfaces, under rocks in ponds, rivers and even aquariums. Flukes are parasites that live in other animals including humans.

Tapeworms are also parasitic flatworms like flukes without a digestive system. It can have fish, cows and pigs as hosts. Humans can be infected with tapeworms if they eat uncooked fish, beef or pork.

Q44. Why do you think parasitic flatworms do not have a digestive system?

Roundworms

Roundworms are members of Phylum Nematoda. Compared to flatworms, roundworms also known as nematodes have long, cylindrical and slender bodies. Some roundworms are free-living while others are parasites of animals and plants. The free-living ones are important as they are decomposers in the soil in both marine and freshwaters. A lot of them are found in decaying organic matter. Parasitic roundworms can be found in moist tissues of plants and animals. Heartworms for example can infect dogs and cats. Humans can be infected with parasitic roundworms such as trichina worms, hookworms and the more common pinworms and *Ascaris* (Figure 20) afflicting children.



(Source: Philippines. Department of Education. (2009). Science and Technology II. Textbook (Rev. ed.). Pasig City: Instructional Materials Development Corporation. p.288).

Figure 20. A male and female Ascaris with its internal parts shown. Digested food is taken in the mouth and exit in the anus.

Q45. Study Figure 20. How many openings does an *Ascaris* body have?

Segmented Worms

The third group of worms among the animal phyla belongs to Phylum Annelida. Also known as annelids, these animals are characterized by a segmented or repeated body parts. This makes them move easily and with flexibility. Annelids are mostly found crawling in moist soil or swimming in sea and freshwaters. Examples of annelids are earthworms, polychaetes and leeches. Most polychaetes are marine living in tubes attached to rocks or sand. They get floating food through the feathery gills. Sandworms are examples of polychaetes.

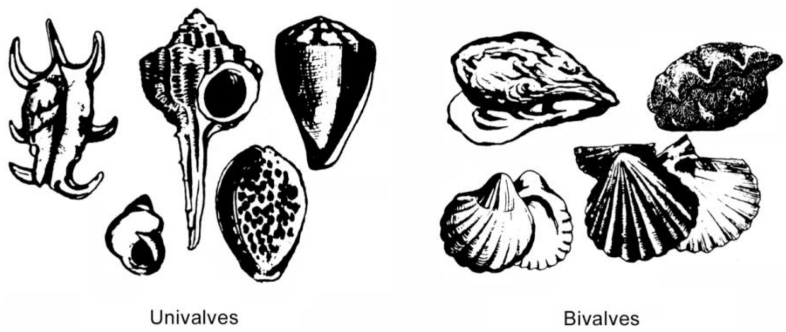
Annelids have nervous, circulatory, digestive and excretory systems. Each segment contains most of the internal structures of these systems. Gas exchange only occurs by diffusion through their skin. This is why earthworms need to be in moist places like under rocks or stay buried in the soil. As they feed and burrow through the soil, they get nutrients and eliminate wastes (castings) through the anus. In this way they aerate the soil and the castings serve as fertilizer.

Leeches are blood-sucking annelids. They have suckers in both ends of their bodies that are also used to attach themselves to their hosts. They secrete an anti-clotting chemical that has been used in medicine.

Mollusks

Mollusks (Phylum Mollusca) are soft-bodied invertebrates with most of them covered by a shell. They have complex respiratory, reproductive, circulatory, digestive and excretory systems functioning together for their survival. The mollusk's body has three parts: a muscular **foot** for locomotion, a **mantle** that produces the shell, and the **visceral mass** that contains their internal organs. Mollusks consist of three classes: the **Gastropods, Bivalves and Cephalopods**.

Q46. Study Figure 21. How would you describe univalves? bivalves?



(Source: Philippines. Department of Education. (2009). *Science and Technology II. Textbook* (Rev. ed.). Pasig City:Instructional Materials Development Corporation. p. 291.)

Figure 21. Examples of mollusks

Gastropods, also called univalves, as you have observed, has only one shell. They are mostly marine with freshwater and terrestrial members. Those living in seas have gills for breathing and those on land use the lining of their mantle as lungs. Sea and land slugs, as well as nudibranchs are examples of gastropods.

You may be most familiar with the bivalves as you see them on your dining table more often. These molluscs as you have observed consist of two shells attached to each other. Some bivalves are attached to rocks while others remain in the sand or mud. They use their mantle cavity to feed by trapping suspended particles in water and for gas exchange. Mussels, oysters, and clams are bivalves.

The cephalopod group include the squid and cuttlefish with internal skeleton. The chambered nautilus has external skeleton while the octopus is shell-less. All cephalopods are described as the most active mollusks, moving very fast using arms and tentacles in catching prey.

Q47. Into which group would you classify *halaan*? the giant African snail?*Tridacna* (*taklobo*)?

Many mollusk species are utilized as food like tahong (mussels), talaba (oyster), halaan (clam), scallops, and kuhol or suso to name some. Other species are made into decorative items.

Golden kuhol, however, has become a pest to rice and other crops. They eat a lot of plant leaves and reproduce rapidly. The giant African snail *Achatina fulica* was found to be an intermediate host to a rat lungworm that causes meningitis.

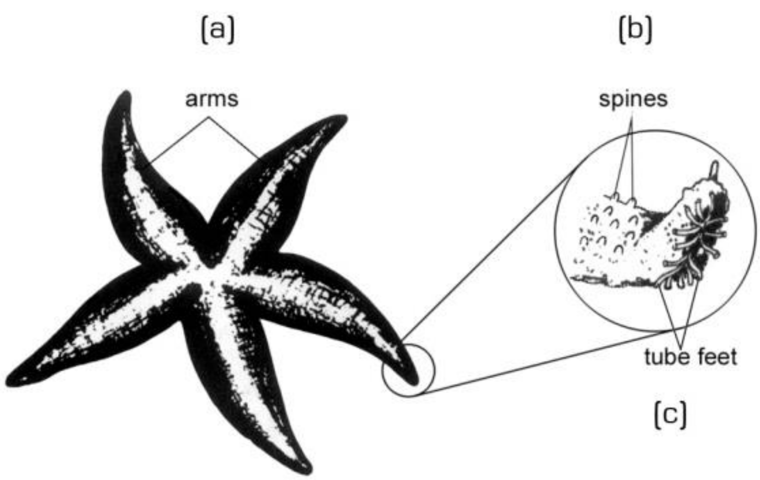
Echinoderms

You can be fascinated by the star-shaped sea star or the spine–studded sea urchin and the appearance of the sand dollar. Along with the brittle star and the sea cucumber, they belong to Phylum Echinodermata. All echinoderms are found in a marine environment. Sea lily, another echinoderm, is rooted in the sand at the bottom of the sea, while sea cucumber burrows in mud of deep or shallow waters.

Parts of most echinoderms radiate from the center of the body. They also have spines which are extensions made of hard calcium. Under the skin, these form an internal skeleton called the endoskeleton.

Sea stars have the ability to regenerate. A cut arm can easily regrow into a new sea star.

Unique to echinoderms is the presence of the water-filled tubes that spread out to form the tube feet (Figure 22). Tube feet are used for getting food, moving around and gas exchange.



(Source: Philippines. Department of Education. (2009). *Science and Technology II. Textbook* (Rev. ed.). Pasig City: Instructional Materials Development Corporation. p. 294.)

Figure 22. Sea star showing (a) arms radiating from the center of the body, (b) spines, and (c) tube feet.

Echinoderm species which are edible include the sea urchin and sea cucumber. *Holothuria edulis,* a sea cucumber, is dried and used as ingredient for chopsuey and soups.

Remember the role of coral reefs in the environment? Sea urchins are important to coral reefs because they consume algae that otherwise overgrow and can kill the corals. In contrast, the sea star, crown of thorns, are predators of coral polyps posing a threat to the existence of the reefs.

Arthropods

Have you observed what grasshoppers, spiders, crabs and centipedes have in common? If you take a look at each of these you will notice that they have jointed legs. These animals belong to Phylum Arthropoda. The group is considered the most successful of all animal phyla as they are present in almost all types of habitats. There are arthropods that walk or crawl, some can fly, while others swim in salty and freshwaters.

Recall in Grade 6, you learned that arthropods have an **exoskeleton**. This is made of chitin and varies from thin and flexible to thick and hard exoskeletons. These animals grow a new skeleton many times in their life to give way to growth, specifically, increase in size through the process of **molting**.

Q48. How do arthropods differ from echinoderms?

Q49. What could be the function of the exoskeleton in arthropods?

Arthropods are grouped based on the type of exoskeleton, the number of body sections and the kind of appendages like mouth parts present. Appendages may be used for avoiding predators, getting food, walking or swimming. **Crustaceans** form one group of arthropods which includes water fleas, crabs, shrimps, lobsters and barnacles. They have hard exoskeletons and have **mandible** to bite and grind food. All crustaceans live in water with the exception of the pill bug. You see it in the soil as the small creature that rolls into a tiny ball when disturbed. Aquatic crustaceans have gills for breathing. Many crustaceans are food to humans. The small ones are eaten by fishes and even whales.

Arachnids have two body sections, most with four pairs of legs and mouthparts called **chelicerae** and **pedipalps**. They use **book lungs** to respire. Spiders with thin and flexible exoskeleton are the largest members of the group. Mites and ticks are parasitic arachnids. They cause itching to some mammals, including humans. Scorpions have a poisonous sting. The horsehoe crab, a close relative of arachnids, is considered the oldest living arthropod.

Millepedes and **centipedes**, close relatives of insects have long, wormlike segmented bodies. They have a pair of antenna and each segment bear a pair or two legs. These animals live in the soil, under rocks or rotting logs and leaves. Millipedes have two pairs of legs per segment and roll up when disturbed. They feed on decaying matter. Centipedes have a pair of legs in a segment. They have venom-containing claws and feed on earthworms, even other arthropods and small animals.

Insects form the largest group among arthropods. They have three body sections, three pairs of legs, a pair of antenna and one to two pairs of wings. Insects are more adapted for flying and have tracheal tubes for respiration. They are present in great numbers in all kinds of environments except in marine waters. Exoskeleton of insects as that of a fly is thin. Insects are also successful animals because they reproduce rapidly. Dragonflies, grasshoppers, aphids, and butterfies are some examples of insects.

Q50. Which arthropod group has no antenna?

Q51. How do legs of insects and arachnids differ?

An important insect that you should learn about is the mosquito. A species of this group, *Aedes aegypti* pose a danger to people of all ages. It carries and transmits through its bite the virus that causes dengue. The following activity will describe how this species reproduce and teach you how to control dengue.

Activity 3
What can you do to prevent dengue?

Objectives:

After performing this activity, you should be able to:

1. describe and classify *Aedes aegypti*,
2. discuss the life cycle of *A. aegypti*,
3. identify breeding places of *A. aegypti*,
4. explain the role of *A. aegypti* in spreading dengue, and
5. suggest ways of preventing dengue.

Materials Needed:

sheet of paper
illustration of life cycle of Aedes aegypti

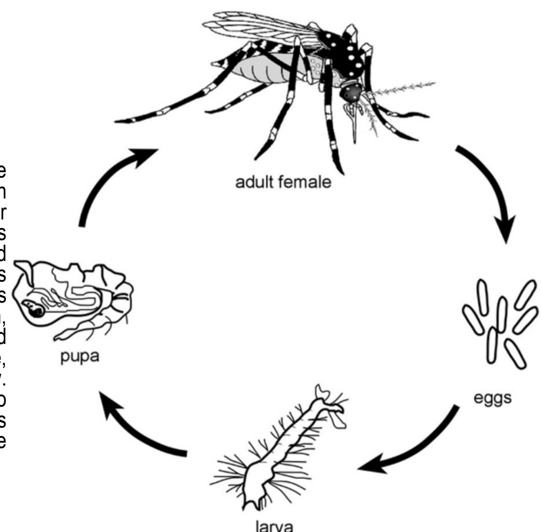
Procedure:

1. Study the different stages in the life cycle of *Aedes aegypti* below.

Life Cycle of Aedes aegypti

Stage IV:

The adult mosquito stay in cool areas on land after hatching. It flies as far as one hundred meters to mate and look for food. The male mosquitoes feed on flower nectar and are usually found near breeding sites. It is the female mosquito that bites animals and people to feed itself with blood. It continues the cycle by laying eggs.



Stage III:

The third stage consists of the comma-shaped pupa which continue to stay at the water surface. The pupa breathes through two small tubes called "trumpets." It dives downwards quickly when disturbed. It stops eating and grows shorter. Then, it encases itself with a hard covering. Inside the pupal case, it continues to change and grow. This stage takes only about two to three days. If the water dries up before the next stage, the organism dies.

Stage I:

Female mosquitoes lay eggs in clean and non-flowing water. Examples are rainwater that has collected in old unused tires and those in flower vases. The eggs are white but later turn into shiny black. Usually this stage may last for only minutes to two days in warm climates but can reach a week in cooler temperatures. Eggs can survive even for a year and are immediately hatched once submerged in water

Stage II:

Mosquito eggs hatch into larva (plural: larvae). It is the second and the most easily seen stage of mosquito development. A larva always lives in water and eats a lot of algae and organic matter. It breathes in air from above the water surface through a tube called siphon. When disturbed, it dives down to the bottom, so it is also called a "wriggler." It returns to the surface to breathe. This stage usually lasts about five to seven days.

Q52. How does the adult of this mosquito look?

Q53. Describe the breeding place of *A. aegypti*.

Q54. In which places in your home, school or surroundings can this mosquito breed? Name at least 5.

Have you heard about "*kiti-kiti*"? These are the larvae or wrigglers.

Q55. What do you think will happen to a larva that is removed from water?

Q56. Based on your study of the life cycle of *Aedes aegypti*, how important is water to the mosquito?

2. Review your answers to Q54.

Q57. What can you do to stop the reproduction of the dengue virus-carrying mosquito? Name at least 5.

Q58. Into what group of arthropods would you classify the mosquito and why?

Chordates

Animals belonging to Phylum Chordata have four characteristics that are present in any of the stages in their life cycle. These are the **notochord**, **the dorsal hollow nerve cord**, **gill slits** and **a post-anal tail**. In many chordates, the notochord later becomes the backbone. Humans being a member of the chordate group have the notochord, tail and gill slits only in the embryo stage.

However, there are lower chordates that do not have a backbone. Examples are the tunicates and lancelets. The adult **tunicates** have only the gill slits present but the larva stages have all the four features. Tunicates attach to solid materials like rocks or coral reefs. They are filter feeders, taking in food particles suspended in water.

Lancelets have the four chordate characteristics present in the adult stage. They live in the sandy ocean bottom. They are also suspension feeders. Lancelets move in a fishlike motion using the muscles on both sides of their body.

Vertebrates

Most vertebrates are sea and land dwellers forming the large group of chordates. The vertebrates' notochord is replaced by the backbone or the vertebral column (vertebra, plu. vertebrae). The nerve cord is enclosed by the projections of the vertebrae. The protected nerve cord enlarges at the anterior end to develop into the brain. The tail can be the bone and muscle that animals use for swimming in aquatic species. For some vertebrates, the gill slits remain till the adult stage. In others, these are modified into structures for gas exchange.

Fishes

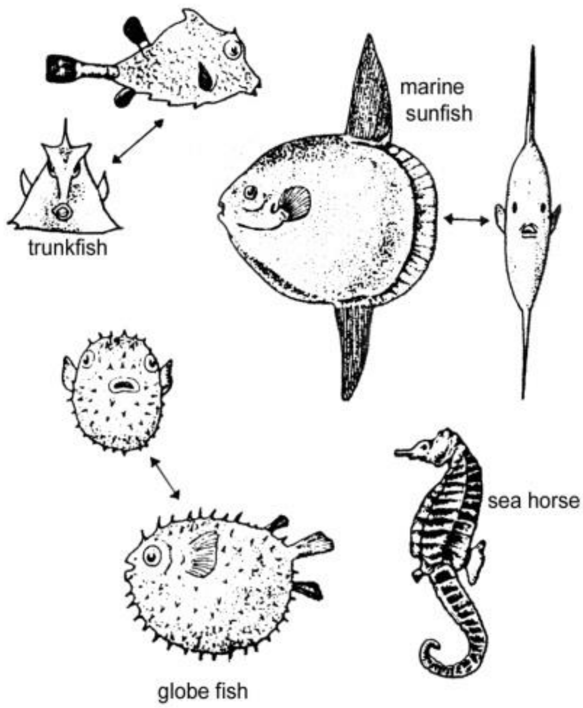
Fishes are vertebrates found in salty, fresh, cold or even hot water. Most have scales for protection, paired fins for movement and gills for gas exchange. Fishes may lay eggs to reproduce or give birth to live young. They are cold bloodied because their body temperature changes when environment temperature changes. Certain fishes do not have true teeth or may be jawless as compared to the others.

Jawless fishes belong to Class Agnatha. Examples are the lampreys and hag fish. Lampreys, being parasites, have tooth-like structures in their mouth that can attach to bodies of other fishes and feed on their tissues and blood. The hagfish is wormlike and use a toothlike tongue to eat dead organisms.

Cartilaginous fishes include the rays, skates and sharks. They have a skeleton made of the soft, flexible protein material called cartilage. Most cartilaginous fishes are covered with a tough, sandpaperlike skin due to the presence of toothlike scales. Skates and rays have winglike fins and move in a gliding motion through the water. Some of them eat floating planktons while others feed on invertebrates at the bottom of seas and oceans.

Sharks may feed on small fishes or on floating algae. The whale shark (*Rincodon typus*), the largest fish, and locally known as *butanding* is found in marine waters of Cebu, Sorsogon and Dumaguete.

The diverse groups of bony fishes belong to Class Osteichthyes. These are the fishes that have an endoskeleton made of hard, calcium material called **bone**. Bony fishes are more familiar to you like *bangus* (milkfish), tuna, goldfish, and *tilapia*. The non-familiar lungfish breathes through the lungs in addition to having gills also for respiration. Eels are wormlike fishes. Figure 23 shows some of the members of the bony fishes.



(Adapted from: Philippines. Department of Education. (2009). *Science and Technology II. Textbook* (Rev. ed.). Pasig City: Instructional Materials Development Corporation. p. 301.)

Figure 23. Examples of unique bony fishes

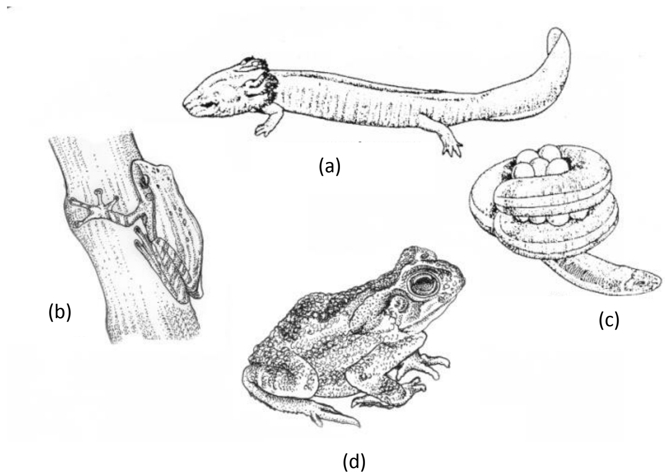
Q59. Compare the skeleton of the shark and the *tilapia*.

As food of humans and other animals, you will learn more about the role of fishes in food chains and food webs which you will study in the next module.

Amphibians

Amphibia means “double life” from which amphibians got their name. This refers to animals that live part in water and part on land. Most lay small, shell-less eggs surrounded by jellylike substance in moist places or in water. These hatch into **tadpoles** with gills and tails. They lose the tail to develop lungs as well as legs and move to land but close to water or damp habitats. They also have moist skin to help the lungs for gas exchange while in dry land. Amphibians are divided into three groups, the **caecilians**, **salamanders**, and **frog** and **toads.** Ceacilians live in water or bury themselves in moist soil. Salamanders live in forest floors under rocks and decaying logs.

Both frogs and toads jump. Some frogs can leap and attach to tree trunks and branches. Toads are terrestrial and can even survive in hot places or desert. Frogs have smooth skin while toads have rough or warty skin. Frogs and toads eat worms, insects or small animals.



(Adapted from: Philippines. Department of Education. (2009). *Science and Technology II. Textbook* (Rev. ed.). Pasig City: Instructional Materials Development Corporation. p. 302.)

Figure 24. Amphibians include (a) the mud puppy, (b) a tree frog, (c) caecilian, and (d) toad

Q60. Refer to Figure 24. Which amphibian(s) is/are tail-less?

Q61. Which of them do not have legs?

Reptiles

Reptiles are animals that exhibit more adaptations for living on land. They lay eggs with shells to protect them from drying. They also have smooth or rough scales for protection from loss of body water.

Lizards and **snakes** have smooth scales. Examples of lizards are the house lizard, gecko (tuko), monitor lizard (bayawak), chamleleon and horned toad. Snakes are legless and have flexible jaws to enable them to swallow their prey whole. A common snake species is the reticulated python seen in zoos. Poisonous species include the cobra and the rattle snake. Snakes however, avoid people and do not attack unless provoked or hurt.

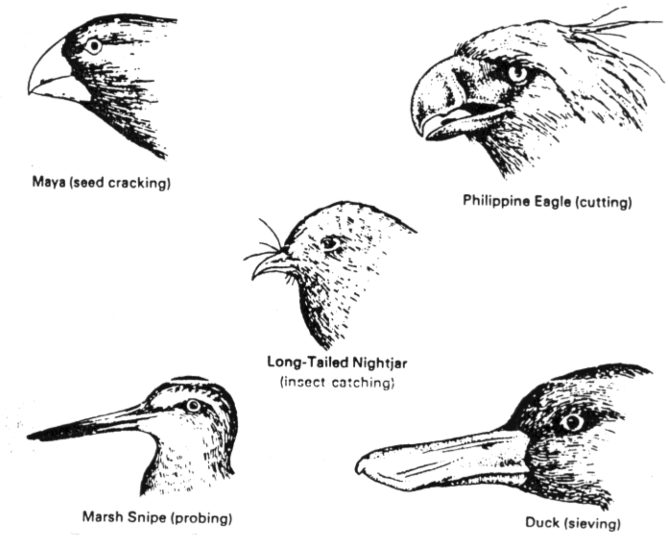
Crocodiles and **alligators** are also reptiles. They are predators of fish, deers, small cows or carabaos, and even attack humans. Alligators live in freshwater and are only found in North and South America. Crocodiles live in fresh and salty waters in tropical and subtropical regions. In the Philippines, two species are present, the endemic *Crocodylus mindorensis* (Philippine Crocodile) and the saltwater *Crocodylus porosus***.** The Philippine crocodile is considered a critically endangered crocodile species in the world.

Bodies **of turtles** and **tortoises** are enclosed in a shell. The head, legs and tail are pulled inside this shell as protection from predators. Tortoises live on land while turtles live mostly in water. *Pawikan* (marine turtles) live in the sea and females come to shore only to lay eggs. There are species of marine turtles which are at present in danger of extinction.

Birds

If reptiles are adapted to land life, most birds are adapted to fly. Characteristics of birds that enable them to fly include: presence of wings and feathers, large flight muscles in the breast bone and reduced weight. Birds weigh less because their bones are light and hollow filled with air. Birds also have eggs with shells and the legs are covered with scales. Their body temperature remains the same despite varying environmental temperature due to the insulation provided by feathers.

Birds have bills or beaks (Figure 25), and in coordination with the type of wings and feet they have, are adapted to where they live and the kind of food they eat.



(Source: Philippines. Department of Education. (2009). *Science and Technology II. Textbook* (Rev. ed.). Pasig City: Instructional Materials Development Corporation. p. 305.)

Figure 25 Different beaks of birds.

Q62. Examine the beak of the Philippine eagle. If it is for cutting, what do you think does this bird eat?

Examples of birds that do not fly are the kiwi, penguin and ostrich.

Q63. Compare the legs of amphibians and reptiles with birds that you are familiar with.

You often eat chicken during meals or even *merienda*. Or maybe *balut* and salted eggs from ducks are your favourites! Snakes and big animals also prey on smaller birds. You enjoy the relaxing chirping or singing of some birds and their varied colors. Although certain birds feed on rice or corn grains, they have a role in dispersing seeds to various places, resulting to perpetuation of many plant species.

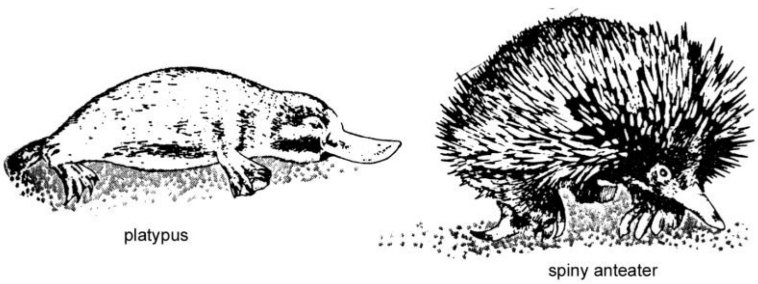
The Philippine Eagle, which is found only in our country, has been declared as a critically endangered species. It means that there is a possibility that the species will disappear or be lost. The main reason is the loss of their habitat-- the forests -- due to logging and their conversion to farmlands.

Q64. If you live somewhere in eastern Luzon, Samar, Leyte or Mindanao where the Philippine eagles specifically live, suggest ways to protect their habitat.

Mammals

Mammals differ from other animals because they have mammary glands that produce milk to nourish their young and most have hair or fur. They breathe in air, have four-chambered hearts and are warm-bloodied. Most of them also give birth to live young and care for them.

The first group of mammals, called **monotremes**, lay eggs similar to those of birds. The spiny anteater (echidnas) living in Australia, New Zealand and New Guinea as well as the duck-billed platypus are monotremes (Figure 26).



(Source: Philippines. Department of Education. (2009). *Science and Technology II. Textbook* (Rev. ed.). Pasig City: Instructional Materials Development Corporation. p. 306).

Figure 26. Examples of Monotremes.

Marsupials or the pouched mammals also give birth to live young. After birth, the young are kept inside pouches and are nourished with the milk from the mammary glands within these pouches. Some marsupials are found in Central and South America. The opossum lives only in North America. Others, such as the more familiar koalas, kangaroos and wombats and flying phalangers, are found in Australia and New Zealand.

The **eutherians** comprise the largest group of mammals. Known as the placental mammals, they bear fully developed young inside the mother's uterus. These young are attached to the placenta through which they receive nourishment until they are born. After birth, they continue to be cared for and nourished by milk from the mammary glands. Table 2 presents the different groups of placental mammals and their representatives.

Table 2. Placental mammals

Order	Characteristics	Examples
Insectivora	insect-eating	shrews, moles
Chiroptera	flying	bats
Rodentia	gnawing	rats, mice, squirrels
Lagomorpha	rodentlike	rabbits, hares
Edentata	toothless	armadillos
Cetacea	aquatic	whales, dolphins
Sirenia	aquatic	*dugong*, manatee
Proboscidea	trunk-nosed	elephants
Carnivora	flesh-eating	dogs, cats, bears, seals, walruses
Ungulata	hoofed foot	horses, zebras, rhinoceros, giraffes, carabaos, goats, pigs
Primates	large brain relative to body size	lemurs, monkeys, apes, humans

(Source: Philippines. Department of Education. (2009). *Science and Technology II. Textbook* (Rev. ed.). Pasig City: Instructional Materials Development Corporation. p. 307.)

Q65. Which of the eutherians live in water?

Q66. In your observation, how do humans differ from other primates?

Primates are the most highly developed of all animals. They are able to walk erect, with fingers and toes adapted to grasp or hang on branches and hold things or manipulate food. They also have a high degree of intelligence. Primates exhibit social behavior like living in organized groups or communities. They take care of orphaned individuals or even fight with competing groups. Scientists would like to believe that the care given by females to their young contribute to their ability to survive.

Q67. What characteristics differentiate mammals from other animals?

Mammals are present in various places, from the very cold to the warmest regions and in salt waters. Many live among humans. Mammals have become an important part of ecosystems. In grasslands, zebras eat plants and in turn are killed and eaten by lions. In forests, bats eat insects and compete with monkeys for fruits. Seeds are then spread for plants to grow in other areas. Wastes of these mammals serve as fertilizers to plants. In human communities, rats carry bacteria and dogs virus that cause diseases. In farmlands, carabaos work for people, while cows, sheep and goats provide meat and milk. Rats destroy crops and compete with humans for rice grains. In whatever way, good or bad, mammals affect the ecosystems where they live.

You have just gone through all the different groups of organisms on Earth known to science at present. You have learned about their similarities and differences. The discussions and activities also showed how they are useful to one another and the whole ecosystem or how some harm others.

Low and High Biodiversity

In the earlier grades you learned that among different ecosystems, the rainforest has the highest biodiversity. This means that it has the greatest number of species living in it. Rainforests have a high rainfall, thus, have lots of plants in them. This condition provides shelter, water and food to many species that can survive drought or disasters as well as competition with other species. This results to a stable ecosystem with lesser rate of species loss. Tropical rainforests are located in places near the equator, while temperate rainforests are found in the temperate regions.

Q68. Based on the discussion above, how will you describe an ecosystem with low biodiversity?

Activity 4
What is the importance of biodiversity to ecosystems?

Objectives:

After performing this activity, you should be able to:

1. differentiate low from high biodiversity,
2. give advantages of high over low biodiversity,
3. identify ecosystems with low and high biodiversity, and
4. predict what will happen to an ecosystem with low biodiversity.

Materials Needed:

photos of different ecosystems
pencil/ballpen

Procedure:

1. Get photos of various ecosystems from your teacher.

2. Together with your groupmates, identify which of them have high or low biodiversity.

Q69. Which ecosystem/s have high biodiversity? low biodiversity?

3. Study the photo below.

Photo by MD Sebastian

Figure 27. A banana plantation.

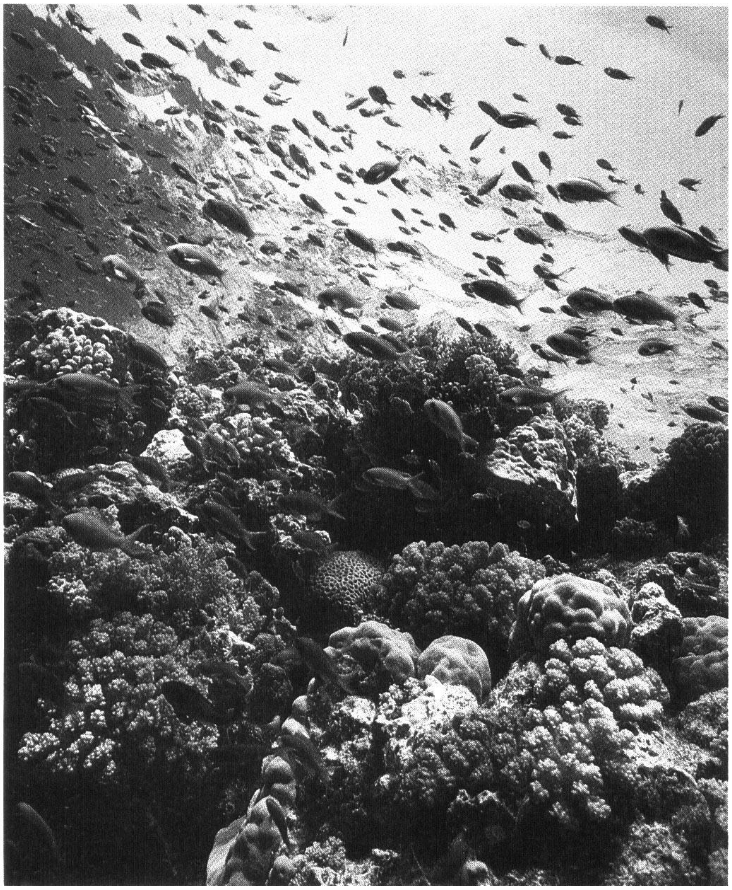
Q70. Does it have a high or low biodiversity?

Q71. What will happen if a pest will attack banana plants?

Q72. What will happen if a strong typhoon comes and heavy flooding occurs?

Q73. How will this affect the helpers and owner of the plantation?

4. Examine the photo below.



(Source: Philippines. Department of Education. (2009). *Science and Technology II. Textbook* (Rev. ed.). Pasig City: Instructional Materials Development Corporation. p. 339).

Figure 28. A coral reef ecosystem.

Q74. What biotic components are present in this ecosystem?

Q75. Describe some relationships and interactions that occur among these biotic components.

Q76. Predict the effect of the presence of many crown of thorns sea star to the ecosystem and its biotic components.

Q77. Why is high biodiversity advantageous over low biodiversity?

Q78. What is the importance of biodiversity to ecosystems?

The North Pole and certain deserts are examples of ecosystems with low biodiversity.

Q79. Give other examples of familiar ecosystems with low biodiversity.

Protecting and Conserving Biodiversity

You have seen that organisms in an ecosystem are interdependent upon each other for survival and harmonious existence. This interdependence among them demonstrates the importance of biodiversity to an ecosystem. You must know however, that as more species are discovered every year, others previously known and identified have decreased in number or have disappeared. A good way to remember the causes of species decline is through the acronym **HIPPO***:

H - Habitat destruction
I - Invasion of introduced species
P - Population increase
P - Pollution
O - Overcollection/overharvesting of resources

Think of the biodiversity in your community at present. What would it look like in the future?

In the following activity, you are going to make a list of conditions that you want to see in your world in the future. Prioritize them, suggest ways and take action to make them happen.

* Threats to Biodiversity. Retrieved from http://www.e-education.psu.edu/geog030/node/394

Activity 5
I create the future[1]

Objectives:

After performing this activity, you should be able to:

1. Make a personal and group vision for the future in relation to biodiversity

[1]Adapted from *Illinois Biodiversity Basics*, a biodiversity education program of the Illinois Department of Natural Resources, Chicago Wilderness, and the World Wildlife Fund

2. Analyze the different ways that government, groups, and individuals are doing in order to arrive at the envisioned future, and

3. Take personal action towards conserving biodiversity.

Materials Needed:

copies of “Priority Pyramid” worksheet and “Making it Happen” handout for each student and for each small group
pencil or ballpen
notebook or sheet of paper for the “future log”

Procedure:

Part I. My Future World

1. As a class, you are going to make a list of conditions that you want to see in your world in the future and then, suggest ways and take action to make it happen. Ask yourself this question: What do you want the future world to be? What things or conditions do you want to see in the world, say, 50 years from now? Make a list of at least five such conditions.

2. Be ready to share your ideas when your teacher will ask the class. Your classmates will be sharing their ideas as well, so listen carefully. Your teacher will write all the ideas on the board. Look at what visions of the future you and your classmates have come up with.

Q80. What conditions do you and your classmates want to see in your future world?

3. Get a copy of the “Priority Pyramid” from your teacher. Complete this pyramid with the conditions that you want your future world to have, ranking them from the most important to the least. Write what for you is the most important condition at the topmost box of the pyramid, the next two conditions on the next level, and so on.

4. You will next share your personal pyramid in a small group. When it is your turn, show your group your pyramid and explain how you chose your top three conditions. When it is the turn of your groupmates to share, be sure to listen to their explanations as well.

5. Now, discuss with your groupmates and create a group pyramid that will represent your group’s priorities for the future. Each one should make a copy of your group pyramid. Decide who among you will present to the class your group’s top three priorities.

6. Compare your personal pyramid to the pyramid that your group came up with.

Q81. Why are there similarities and differences?

Q82. How do you feel about the final result, that is, the group pyramid?

Q83. How do you feel about the process you went through to come up with the group pyramid?

Part II. Making it Happen

Q84. Will our dreams for the future come true by simply thinking about them?

1. Look at the different blocks (conditions) on your group pyramid. Are you aware of anything that you or other people are already doing to ensure that these will happen in the future? Make a list and discuss these with your groupmates.

Q85. Do you know of any ongoing programs, initiatives and legislations related to these priorities?

Q86. What government agencies, organizations, groups and individuals are responsible for or are working on the conservation of biodiversity, either locally or on a global scale?

2. Obtain a copy of the "Making it Happen" handout from your teacher. Read about each of the projects and choose those that you think are making or will make significant contributions to meeting the top three priorities in your group pyramid. For each project that your group will choose, write a sentence or two to describe ways it is working to achieve the identified priority. You can also add what your group thinks as the project's strongest and weakest points.

Part III. I Can Make a Difference!

Q87. What can you do to create a positive future?

1. Keep a "future log" for a week. Your log should list in bullet form, all your activities, behaviors, speech and thoughts for each day. At the end of each day, think about and write down how each bullet item affects the world around you, either positively or negatively, and what consequences it could have for the future.

2. Each day, add ways that you can do more to help preserve the earth's biodiversity.

Q88. What changes in your daily actions can you carry out to contribute to conserving biodiversity?

Remember that the biodiversity found in your community, are what you need to live and survive. As students, start right by taking seriously your learning and understanding of your community's biodiversity, the organisms' importance to and interactions with each other. Use them wisely and conserve biodiversity. It is only when you understand all of these will you realize that you cannot afford to lose any of these, for all of you and your future, will be affected. "ACT NOW, NO ONE CAN DO THIS FOR YOU NOR FOR US!"

In the next module, you will be introduced to more ways by which these organisms affect and interact with each other as well as with the environment they live in.

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Suggested time allotment: 5 to 6 hours

Unit 4
MODULE
2

INTERACTIONS

Overview

In Module 1, you have learned about the diversity of organisms. Based on the body structures and functions, organisms are classified using the hierarchical taxonomic system (i.e. domain, kingdom, phylum, class, order, family, genus, and species). Scientists use this system of classification to organize information and to understand why living things exist the way they do in a particular environment. Also, this helps us understand the role of each organism in the environment.

All these organisms need energy to sustain life. Every activity that organisms do in ecosystems—breathing, moving, running, burrowing, growing—requires energy.

The flow of energy is the most important factor that controls what kinds of organisms live in an ecosystem. In this module, you will learn how organisms obtain energy. This includes the discussion on how producers and consumers make possible the flow of energy through ecosystems through food chains and food webs. Students will then discover how the reduction in the amount of available energy limits the number of steps that can occur in a food chain. Students will then identify the role of bacteria in the cycling of some important elements or substances such as water, oxygen, carbon and nitrogen.

How does energy become transferred from one organism to another?

In Grade 7, you have learned that plants, some kinds of bacteria, and algae are capable of converting energy from the sun into chemical energy and store it as chemical energy known as food. These organisms are called producers**.** The process is called photosynthesis; it uses water, carbon dioxide, and sunlight.

Most plants make much more food each day than they need. Plants may convert excess glucose into starch. Starch may then be stored in other parts of the plants such as roots and fruits.

The stored energy is transferred to other organisms for their survival. When people and other organisms eat plants, chemical energy from food substances is transferred to their bodies. Energy moves from one trophic level to another. This means that energy flows from one organism to another in the ecosystem. Organisms that consume food for their energy supply are called consumers**.**

Q1. What raw materials from the environment are needed in the process of photosynthesis?

Activity 1
How do you identify the components of a food chain in an ecosystem?

Objectives:

After performing this activity, you should be able to:

1. distinguish between producers and consumers.
2. analyze the transfer of energy from one organism to another.
3. construct a food chain in a given ecosystem.

Materials Needed:

an article about “Monfort Bat Cave”
Activity sheet

Procedure:

1. Read an article about "Monfort Bat Cave."

2. Read the following questions, and write your answer on the space provided.

The Island of Samal, part of Davao del Norte Province, is off the coast of Mindanao. In this island is the Monfort Bat Cave which is approximately 245 feet (75 meters) long and has five entrances. Bats cover 75 percent of its ceilings and walls. An estimated 1.8 million bats, the largest known population of Geoffroy's rousette fruit bats in the world, are overloading Monfort Bat Cave on the Philippines' Samal Island.

Photos courtesy of: Rodolfo S. Treyes, UP NISMED

Figure 1. Geoffroy's rousette fruit bats clinging on walls and ceiling of the cave.

Geoffroy's rousette fruit bats feed on fruit and nectar. Their role as pollinators and seed dispersers is essential in sustaining Philippine forests, including such important commercial fruits as durian. Each bat consumes 1½ to 3 times its body weight nightly in fruit and nectar. This colony could consume 550 tons (500,000 kilograms) of nectar from durian and other trees, pollinating an incredible number of flowers.

Worldwide, cave-dwelling bats are in alarming decline due to human disturbance and destruction of their cave roosts. In some areas, including Samal Island, bats are captured and eaten by humans. Colonies like the one in Monfort Bat Cave are now rare and in urgent need of protection. Their loss would endanger the health of forests and human economies.

The bat's colony should be able to survive natural predators – crows, rats, 10-foot (3-meter) pythons and occasional monitor lizards – just as bat populations do elsewhere. Untamed dogs and cats, however, also seem to do bat hunting at Monfort Bat Cave.

Q2. What are the organisms found in the surrounding area of Monfort Bat Cave? List them down in the table below.

Table 1. Organisms found in Monfort Bat Cave

Plants	Animals

Q3. What group/s of organisms are considered as producers?

Q4. What part of the durian trees and other trees served as food for the bats?

Q5. The population of cave-dwelling bats is declining because they are being eaten by other organisms. What are these organisms that feed on bats?

Q6. Among the organisms that feed on bats, are there organisms that possibly feed on the predators of bats? ___ Yes ___ No

3. Divide the organisms into the following categories as shown in the table below:

Table 2. Categories of organisms living in the Monfort Bat Cave

Producers	1st Order Consumer	2nd Order Consumer

4. Based on Table 2, construct a food chain with at least 3 organisms representing the producer, 1st order consumer and 2nd order consumer.

Energy from the Sun	→		→		→	
		Producer		1st order consumer		2nd order consumer

Q7. You have just analyzed the transfer of energy by categorizing the organisms according to their trophic level. In your own words, describe a food chain.

Food chains may be interconnected to form a food web. For example, one kind of food may be eaten by several consumers. Or several foods may be eaten by one consumer. A simplified food web in a Philippine forest is shown in Figure 2.

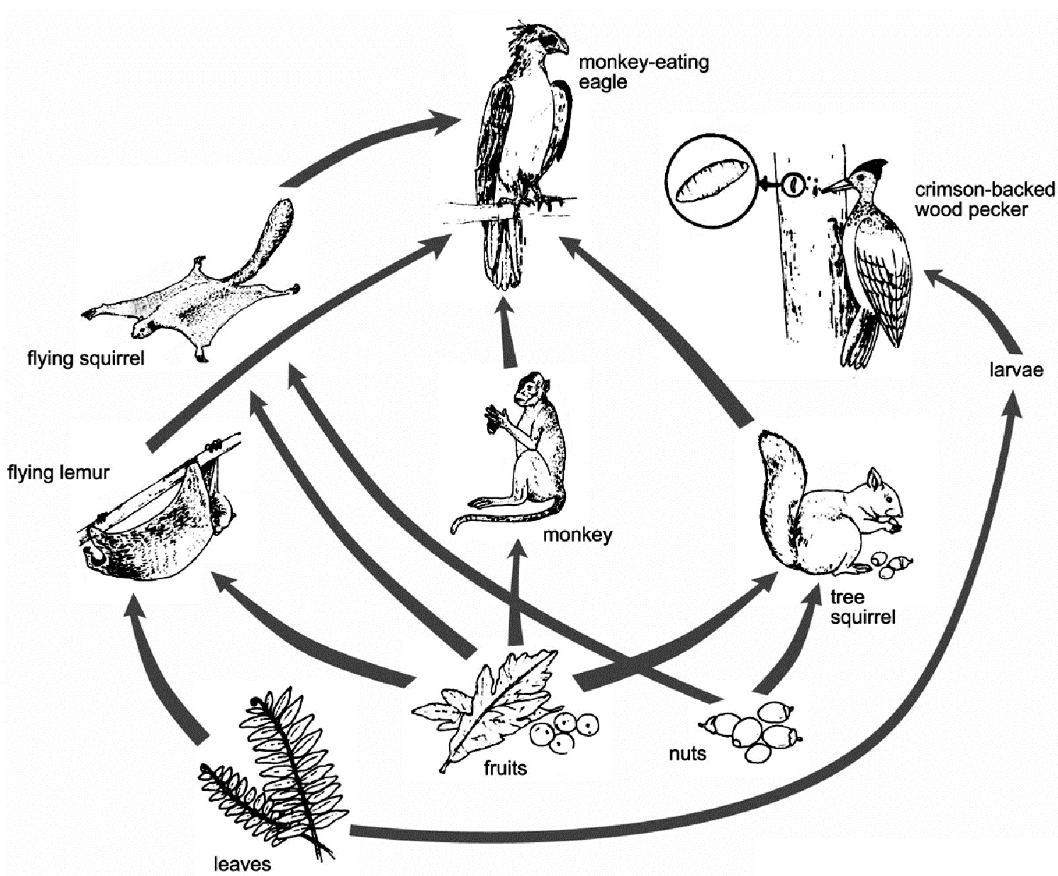


Figure 2. Interconnected food chains comprise this simplified food web in a forest. Many organisms, including the decomposers, such as bacteria and fungi are not shown in this food web.

Figure 3 shows a simplified food web in a marine environment. Microscopic algae serve as the producers which are eaten by zooplankton. Zooplankton, in turn, are eaten by small fish and other marine organisms.

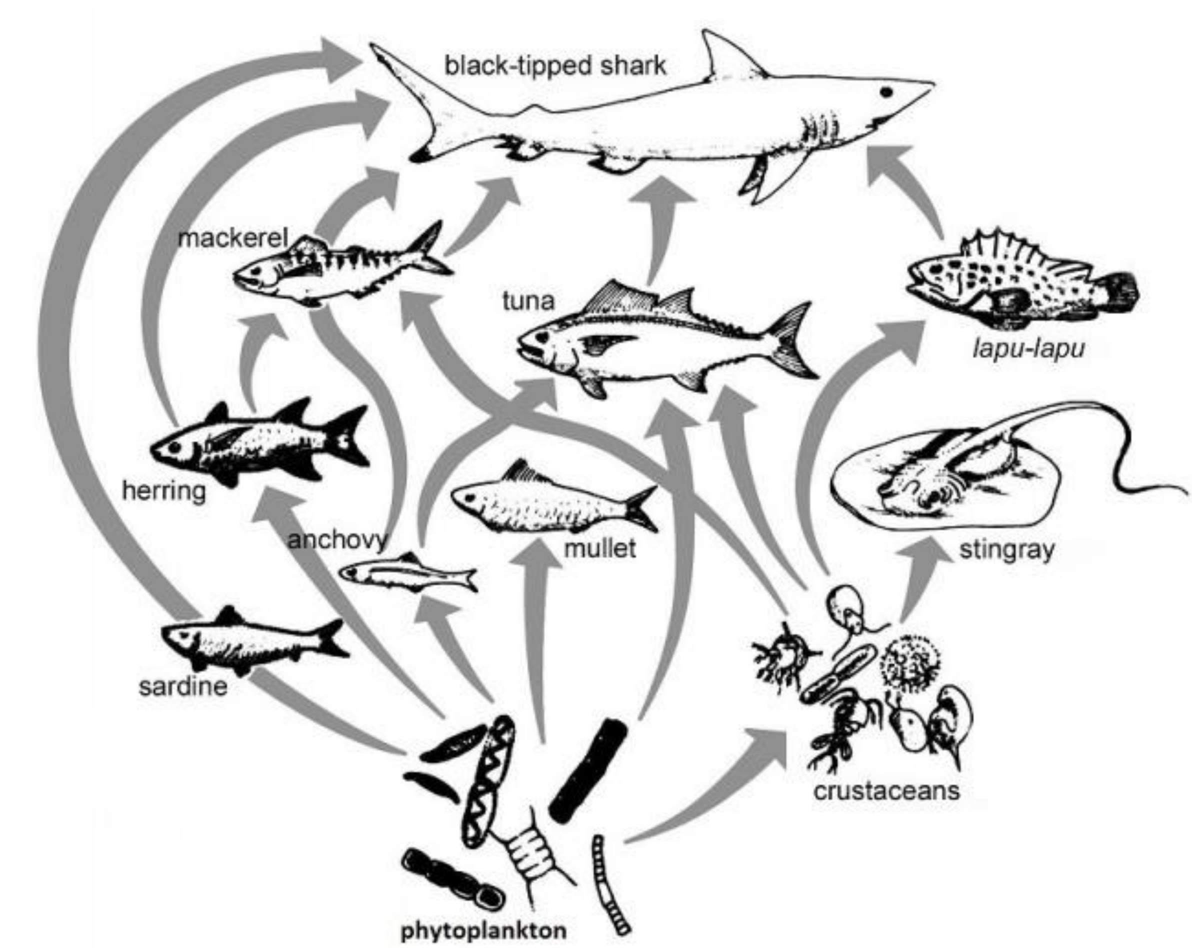


Figure 3. Simplified food web in the sea illustrates the interconnected feeding relationship between sea organisms.

The food web in Figure 4 includes a third group of organisms. Besides the producers and the consumers, the food web shows the decomposers consisting of bacteria and fungi. Decomposers act on dead organisms and change these to simple nutrients which plants can use again.

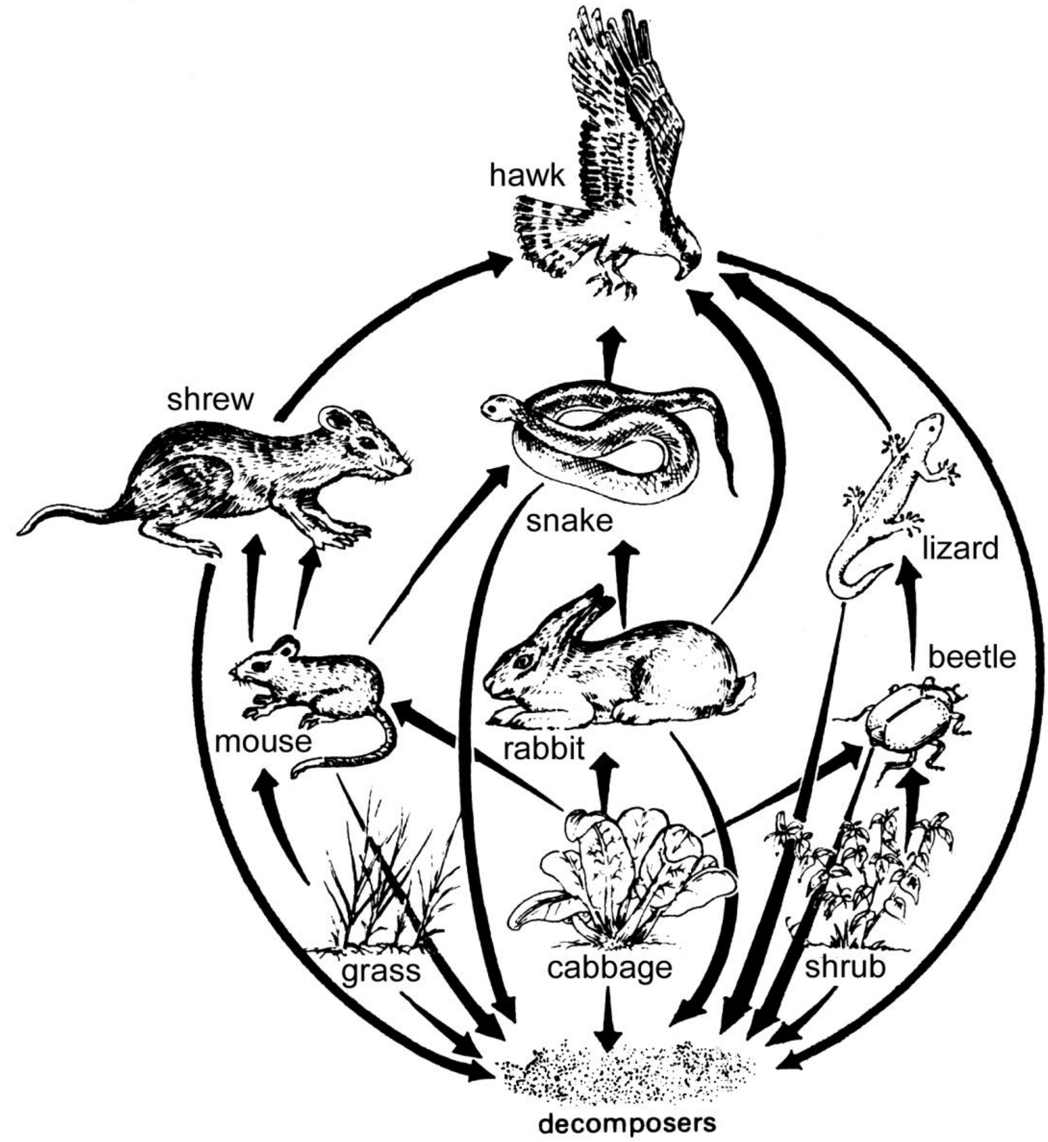


Figure 4. The flow of food in this food web is from producers to consumers to decomposers.

Q8. Without decomposers, will producers and consumers stay alive? Why?

Q9. Without producers, will consumers stay alive? Why?

Activity 2
Making food webs

Think of the food your family ate for supper last night. Make a food web based on your meal. Remember, your food web must have producers, consumers, and decomposers.

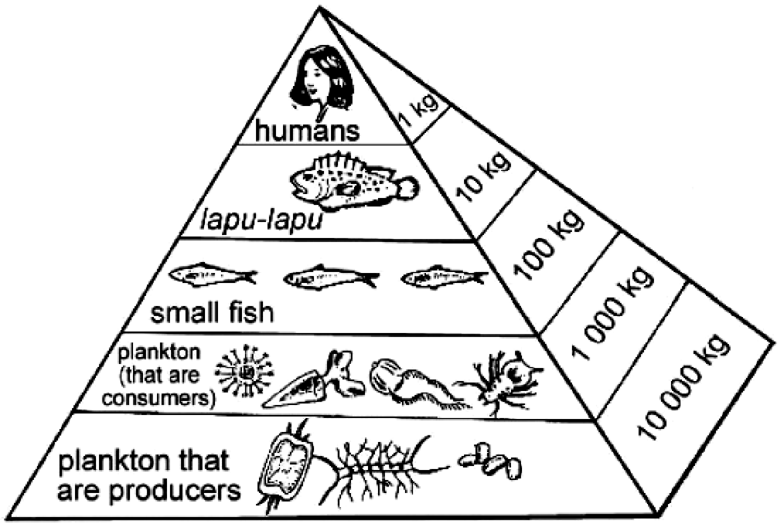
Q10. To which group of organisms do you belong?

Q11. Which trophic level do you occupy?

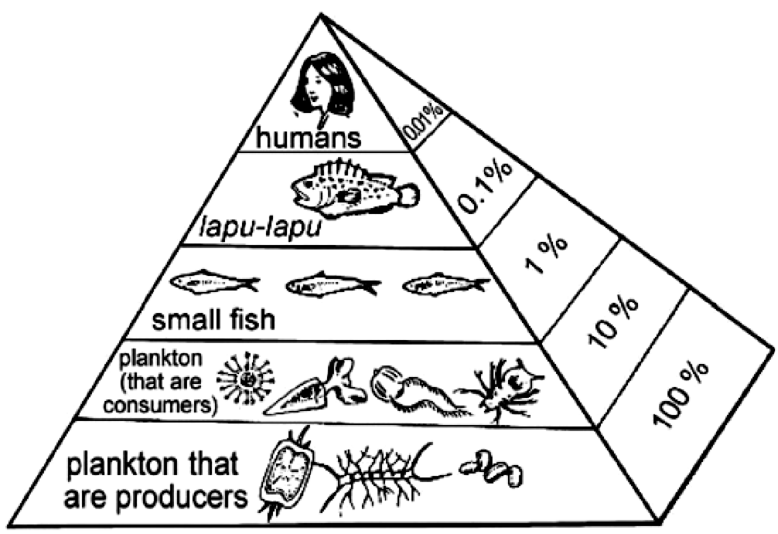
Food Pyramid

When organisms eat, they take in matter as well as energy into their bodies. For example, when you eat chicken, the flesh of the chicken containing nutrients and energy enters your body. You use the nutrients and energy to build muscles and other parts of your body and to perform various activities.

The transfer of matter expressed as biomass and energy in food from one trophic level to another are not one hundred percent used. **Biomass** is the total mass of organisms in a food chain or a food web. Not all plants or animals at one level are eaten by organisms at the next level. Some parts of plants or animals are not edible, for example, wood, peel of some fruits, some seeds, shells, and bones. In addition, much of the energy is lost as heat. Only about 10% of biomass and energy are transferred to the next level. This relationship between producers and consumers can be demonstrated through a biomass pyramid and an energy pyramid (Figure 5). In the case of the marine environment, the source of energy in the food chains is also the Sun.



pyramid of biomass



energy pyramid

Figure 5. The idealized pyramids of biomass and energy show losses at each trophic level.

What do these pyramids demonstrate? A large amount of producers at the base of the pyramid will be needed to support only a few of the consumers at the top. The largest amount of biomass and energy are at the base of the pyramid. A decrease or loss occurs at each succeeding level. As shown in Figure 5, 10 000 kg of plankton that photosynthesize are needed to support only 1 000 kg of plankton that do not photosynthesize. Planktons that photosynthesize are producers used as food by the planktons that do not photosynthesize, the primary consumers. In turn, 1 000 kg of the primary consumers would support only 100 kg of small fish, which in turn would sustain only 10 kg of lapu-lapu. At the highest level are humans. Note that 10 kg of lapu-lapu would sustain only 1 kg of the biomass of humans. Due to the loss of biomass at each level, 10 000 kg of plankton at the base of the pyramid would support only 1 kg of humans who are the top consumers.

In an energy pyramid the base of the pyramid is reduced and only 10% moves to the next level. This loss goes on at every level until only 0.01% reaches the top consumers.

Consider the food web in Figure 5. A food web can also fit into an energy pyramid. It shows the flow of food through different organisms living in an area.

Construct an energy pyramid based on the food web. Include only the producers and the consumers. Exclude the decomposers for a while.

Q12. Which group of organisms has the greatest biomass? Which has the greatest energy?

Q13. Which group of organisms has the least biomass? Which has the least energy?

Q14. What happens to the amount of biomass from the bottom to the top of the pyramid?

Activity 3
Meat eaters vs. plant eaters

What can you infer from the biomass pyramids below?

1. Study the following pyramid of biomass.

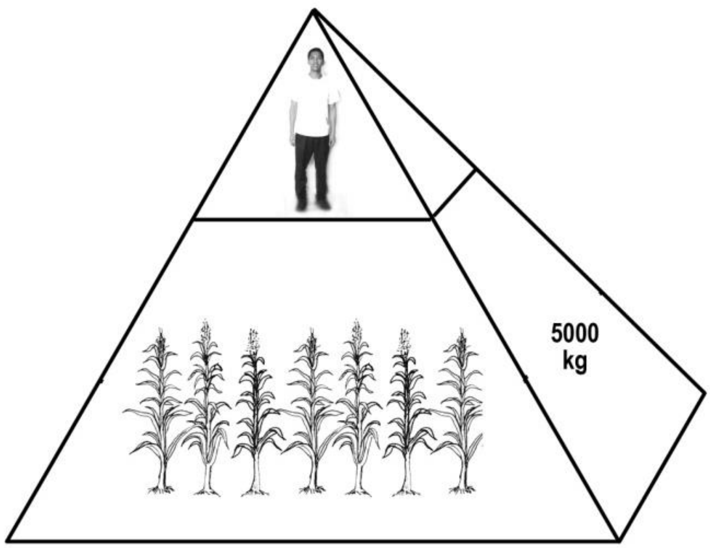


Figure 6. Pyramid of biomass

Q15. How much biomass of humans can 5 000 kg of corn support?

2. This time, study the following pyramid of biomass.

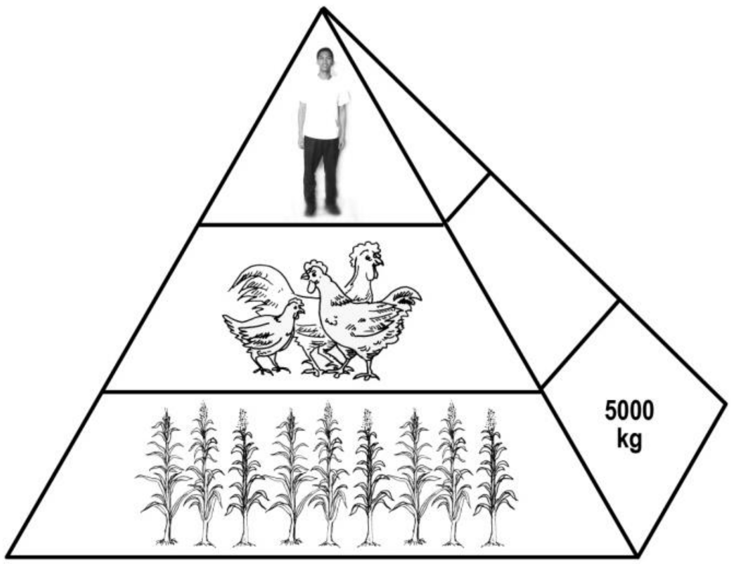


Figure 7. Pyramid of biomass

Q16. How much biomass of chicken can 5 000 kg of corn support?

Q17. How much biomass of humans can the chickens support?

Q18. Which is more efficient in converting biomass of producers to biomass of consumers – a meat eater or a plant eater? Give your explanation.

Cycling of Materials in the Ecosystem

Materials in the ecosystem cycle constantly. This cycling of materials includes the oxygen-carbon dioxide cycle, the water cycle, and the nitrogen cycle.

The Oxygen-Carbon Dioxide Cycle

Organisms use and produce gases in photosynthesis and respiration. These gases flow through organisms and the environment in a cyclic process called the **oxygen-carbon dioxide cycle (**Figure 8). The oxygen-carbon dioxide cycle shows the interdependence among organisms for these important gases.

When plants photosynthesize, they use carbon dioxide and produce oxygen. Oxygen produced by plants in photosynthesis is used by animals when they respire; animals in turn produce carbon dioxide. Like animals, plants also carry out the process of respiration. During respiration, plants use oxygen and produce carbon dioxide.

Animals take in oxygen from the atmosphere and give off carbon dioxide during respiration. This occurs day and night. Plants, however, give off oxygen and take in carbon dioxide when they photosynthesize during the day. At night, when plants are in darkness and cannot photosynthesize, they "breathe" just like animals. They take in oxygen and give off carbon dioxide.

Notice that plants and animals depend on each other for these important gases. Plants produce oxygen needed by animals. In turn, animals produce carbon dioxide needed by plants.

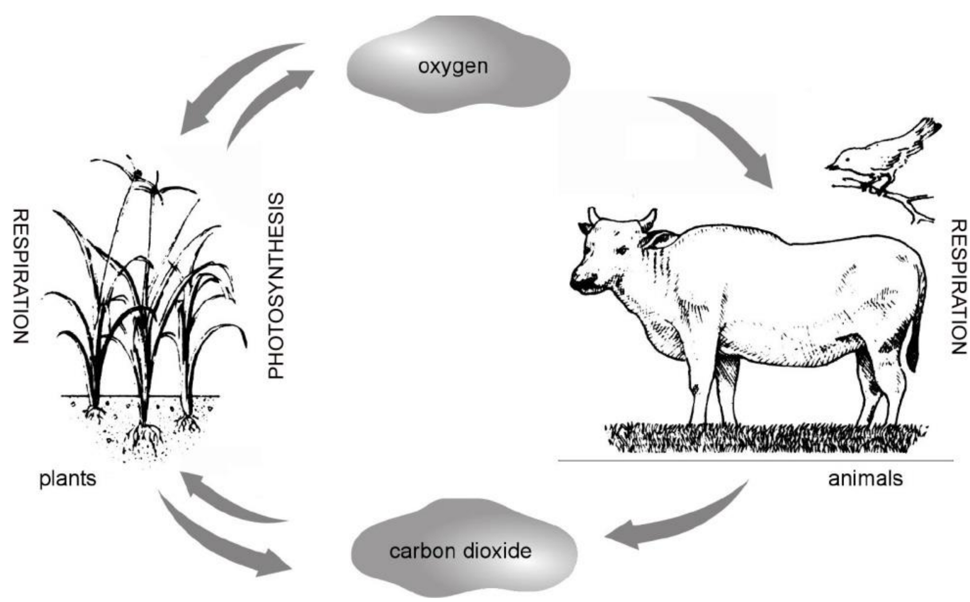


Figure 8. Oxygen and carbon dioxide are continuously availed of by plants and animals through the oxygen-carbon dioxide cycle.

Q19. What gas do plants produce that animals use?

Q20. What gas do animals produce that plants use?

The Water Cycle

Water circulates around the environment – the oceans, land, air and living organisms. The cycling process involves evaporation, transpiration, condensation, and precipitation. When solar energy warms the Earth's surface, water evaporates from the oceans, rivers, lakes and land. The escape of water through leaf pores (transpiration) adds water vapor to the atmosphere. Upon cooling at higher altitude, water vapor condenses and forms clouds. Eventually, precipitation occurs in the form of rain or snow. On land, plant roots absorb water. In trophical rainforests, over 90 percent of the moisture is cycled through transpiration in plants. Some water seeps downwards and replenishes the ground water. The excess eventually overflows into the oceans and the water cycle continues

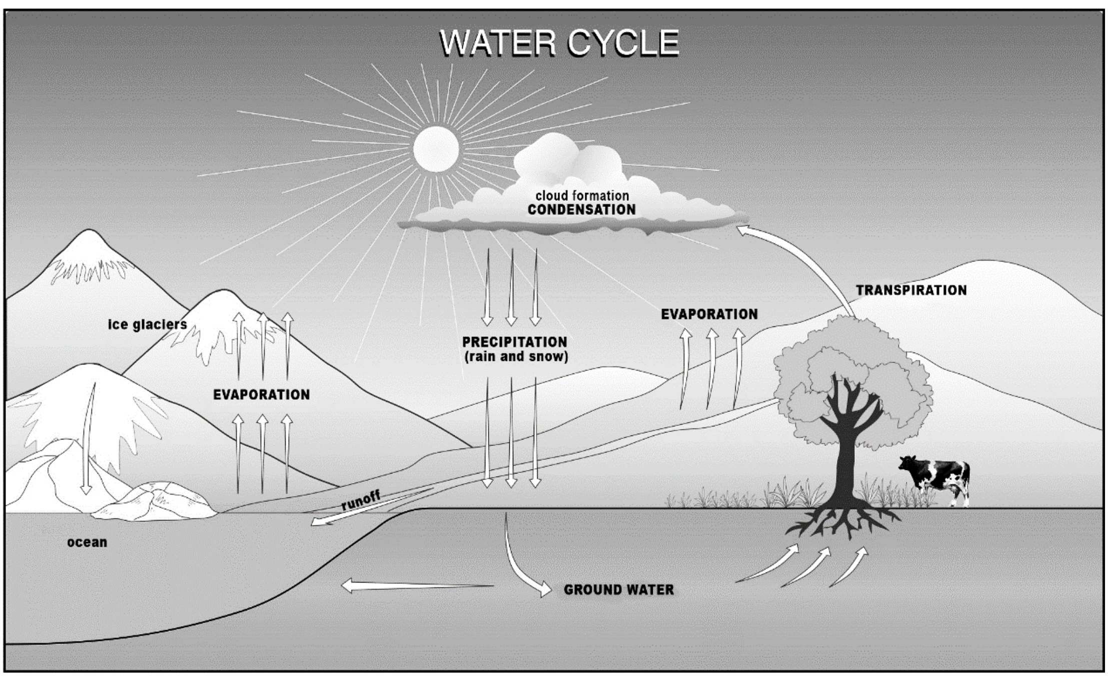


Figure 9. The Water Cycle.

The Nitrogen Cycle

About 79 percent of the gases in the atmosphere is made up of nitrogen gas. Organisms use nitrogen to build proteins and nucleic acids. Some bacteria convert nitrogen to ammonia. This process is called nitrogen fixation. Nitrogen-fixing bacteria live in soil and are abundant in the nodules of legumes such as mung beans.

The nitrogen cycle, shown in Figure 10, is a complex process with four important stages.

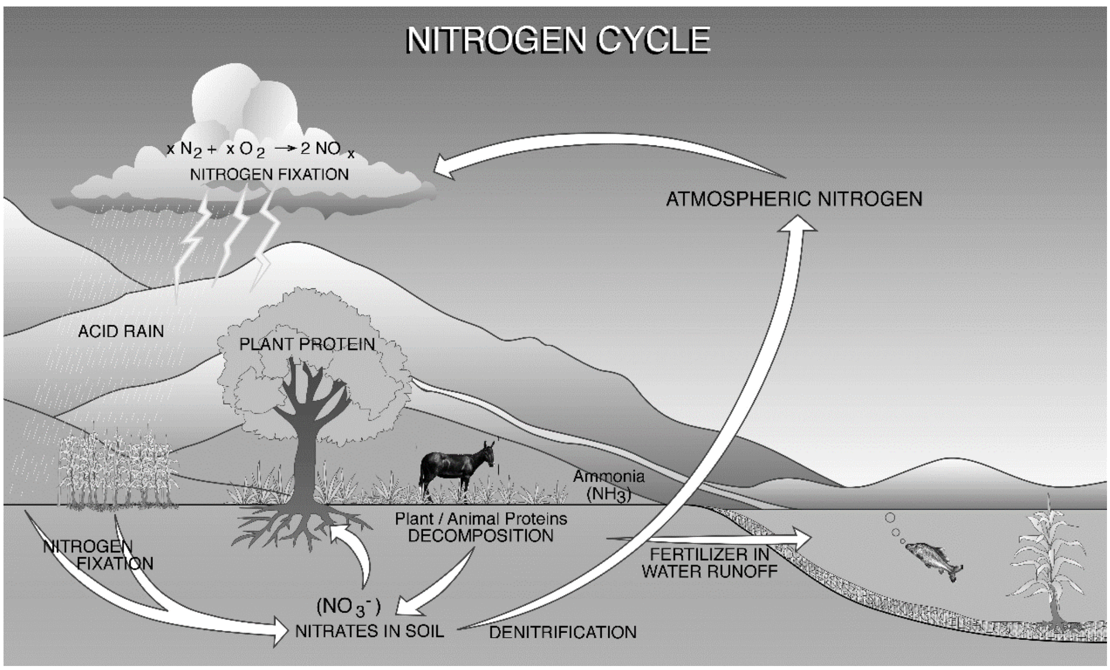


Figure 10. The Nitrogen Cycle.

How do Human Activities Affect the Ecosystem?

Humans are the top consumers in many food pyramids. To increase food production, they use methods that have an effect on food chains and food webs. Some of the farming practices are described as follows:

Monoculture. This is the cultivation of a single crop in large areas. Vast tracts of land are converted to rice farms, sugar farms, and coconut farms.

By limiting the cultivation of different kinds of plants, people also deprive many animals of their food and home. These animals, some of which feed on insect pests, move to other places. Only the insect pests that eat the monocrop remain in the area. If uncontrolled, these pests can totally wipe out the monocrop in a short time.

Some soil microorganisms depend on specific plants for food. Eliminating these plants is harmful to the microorganisms. Since microorganisms are responsible for returning plant nutrients to the soil, the cycling of nutrients for reuse of the plants is disturbed.

Herbicides and Insecticides. Farmers spray their crops with insecticides to kill insect pests, and with herbicides to kill weeds. However, the chemicals also destroy other organisms, including beneficial insects and soil organisms which help in decay.

Insecticides move up the food pyramid and accumulate in the body of organisms. The smallest concentration of the chemical is at the base of the pyramid occupied by producers. The amount increases towards the top. The greatest concentration is found in the top consumers such as birds, mammals, and humans.

Many insect pests become resistant to chemicals. This may lead to the use of increased amounts of pesticide.

Chemical Fertilizers. Monocrops usually require large amounts of chemical fertilizers. Continuous and uncontrolled use of chemical fertilizers may increase soil acidity, thus destroying soil structure. Findings show that more fertilizers are needed for the same amount of yield after years of monoculture.

Fertilizers may run off to rivers, ponds, and lakes. Accumulation of fertilizers may cause the death of these bodies of water.

Fertilizers in the water will cause increased growth of algae and other water plants. They cover the water's surface and block the passage of oxygen. Thus, less oxygen is dissolved in water. Furthermore, when algae and aquatic plants die, decay microorganisms use oxygen. Dissolved oxygen becomes insufficient, causing fish and other aquatic animals to die.

Q21. Describe one way by which the following practices may disrupt a food chain or food web:

1. monoculture
2. use of insecticides
3. use of fertilizers

To conserve the environment, some desirable practices are described below.

1. Grow a variety of crops instead of only one crop.

2. Use insects to fight other insects. This is known as biological control of insect pests.

3. Instead of chemical fertilizers, try organic farming using natural fertilizers for crops. Some natural fertilizers are compost and animal manure.

You may interview a farmer to get his or her opinion on these desirable practices. Also ask if there are other good practices that the farmer uses in the farm.

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Suggested time allotment: 8 to 10 hours

Unit 4
MODULE
3

THE DIGESTIVE SYSTEM

Overview

Food plays a central role in the survival of species. Food gives organisms energy that enables them to carry out the many activities they do each day; this includes predators chasing a prey or a prey escaping a predator, arboreal organisms climbing trees to gather fruits, or fish swimming in schools in search for food, to name a few. Organisms are able to obtain energy from the foods they eat through digestion.

Digestion of food is carried out by the organs and substances of the digestive system. During digestion, food is broken down to smaller parts -- a fraction of which is made up of nutrients. These nutrients are circulated to the different parts of the body through the bloodstream and assimilated by cells.

Almost all animals have a **digestive system** in which food enters the mouth, is moved through a long tube, and exits the anus as feces. The food is broken down into soluble molecules and is moved rhythmically by the smooth muscle in the walls of the digestive organs.

Different species of organisms have different ways of digesting their food. In humans, digestion starts in the mouth where food is chewed and broken down to smaller pieces for easier digestion. This is called **mechanical digestion**. Initial **chemical digestion** starts also in the mouth. This is carried out by **enzymes** -- molecules that speed up chemical reactions. Enzymes present in saliva such as amylase helps break down carbohydrates, which are large complex molecules, into simpler ones that can be used by the body.

After swallowing, the food -- now turned into a bolus -- enters the esophagus (gullet) and is moved down into the stomach where it mixes with gastric juices and acids. Other enzymes such as protease and lipase help break down proteins in the stomach and fats in the small intestine, respectively. Digestion ends in the small intestine where nutrients are absorbed in the villi and enter the circulatory system. Wastes that remain after digestion go to the large intestine where water is also reabsorbed. These wastes, including the water that was not reabsorbed, are temporarily stored in the rectum before they are excreted out of the body through the anus.

Digestion in other organisms works similarly. However, there are specialized structures found in some species that perform special digestive functions.

This module introduces you to the different organs that make up the digestive system of animals and how they interact with each other to digest food and nourish their bodies. Emphasis is given on the human digestive system and its processes.

How does the digestive system break down food to nourish the body?

Activity 1
Part 1A. A gutsy game

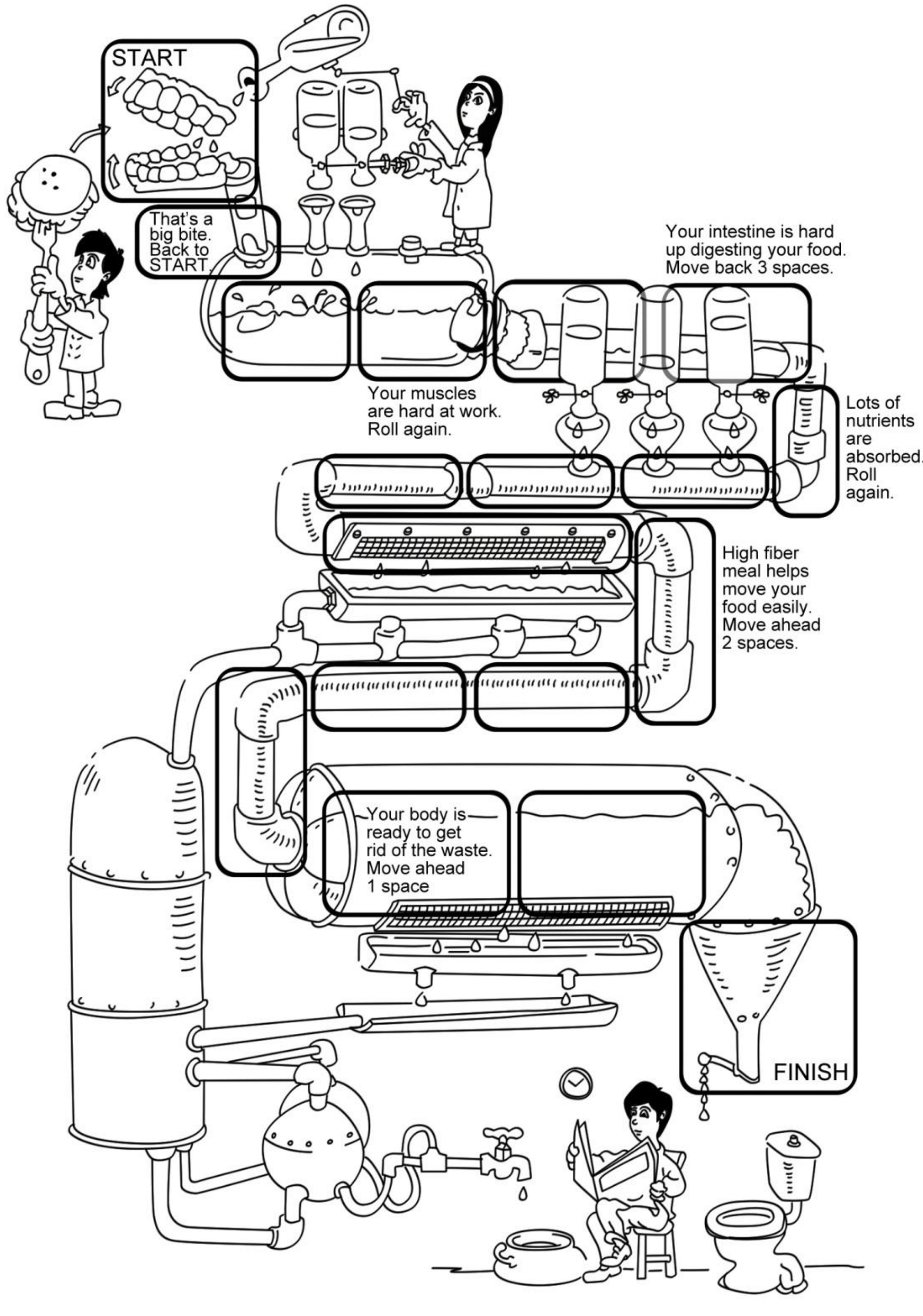
Objectives:

After performing this activity, you should be able to:

1. identify the organs that make up the digestive system; and
2. describe the function of each organ.

Materials Needed:

game board (refer to following page)
a piece of die
tokens or playing pieces


START
That's a big bite. Back to START.
Your intestine is hard up digesting your food. Move back 3 spaces.
Your muscles are hard at work. Roll again.
Lots of nutrients are absorbed. Roll again.
High fiber meal helps move your food easily. Move ahead 2 spaces.
Your body is ready to get rid of the waste. Move ahead 1 space
FINISH

Procedure:

1. Find a classmate with whom you can play the board game.

2. Choose a token for you and your classmate; place the tokens on the board's starting line.

Q1. The game you are about to play is an analogy of the digestive system. What do the tokens represent?

3. Take turns rolling the die.

4. The number on the die determines how many spaces you will move your token.

Q2. What do the spaces on the board game represent?

5. Follow the directions -- if there is any -- on the space you land your token.

Q3. What do the directions on some of the spaces tell you about the digestive system?

6. The player who first makes it all the way through the digestive system and down to the finish line wins the game.

In Activity 1, you should have inferred that the digestive system is made up of different organs that work together to break down food and nourish the body. Describe the illustrations on the board game. What do these illustrations represent? What do the spaces or boxes drawn on the board game represent?

Notice that the board game is just an analogy of the structures of the digestion system and the processes they carry out. Refer to Figure 1 to compare the illustrations on the board game with the actual structures or organs of the digestive system.

Are these structures also found in other organisms? Are these structures in the digestive system of humans the same as those found in other organisms? Do they serve the same or similar functions?

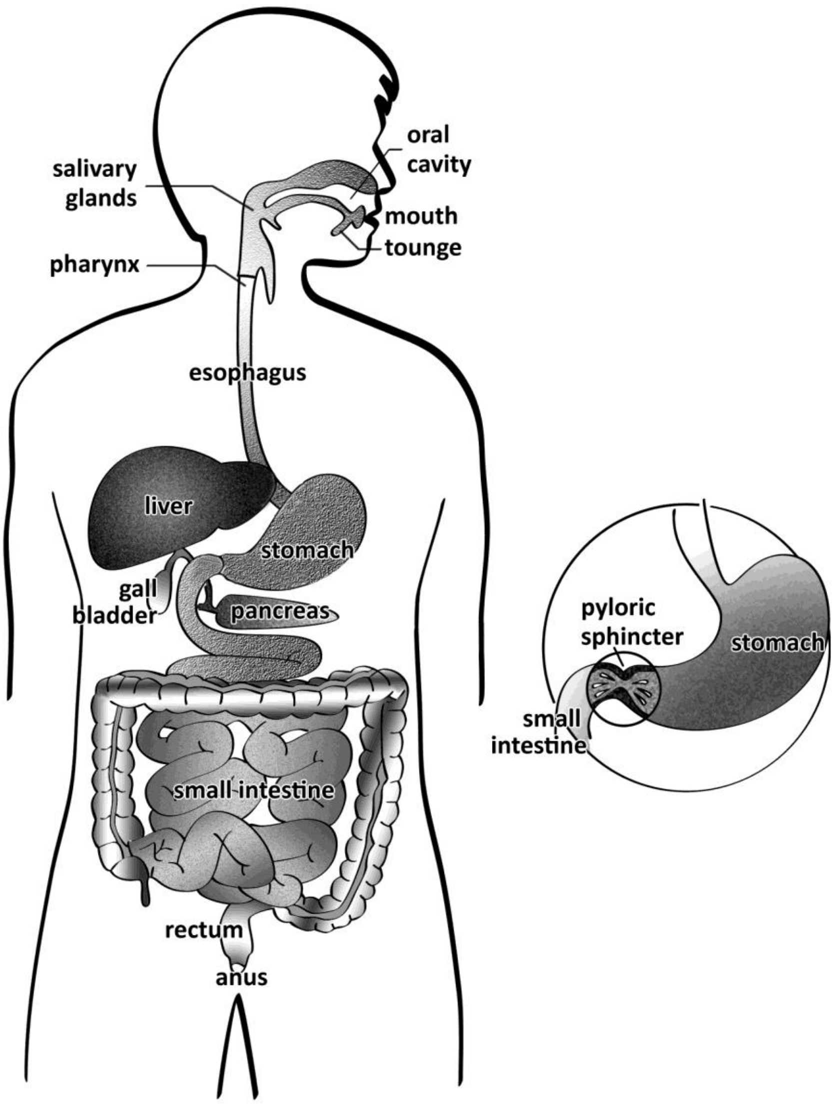


Figure 1. The human digestive system.

The digestive systems of animals and the organs that make them up vary across species. Some structures like the *rumen, crop, and gizzard* are found only in some species. The rumen is common among ruminants that include the goats, cows, and carabaos. What do you think is the function of this structure? The crop and gizzard are found in birds and some species of invertebrates like the grasshoppers and earthworms. What functions do you think do these structures perform in digestion?

Almost all animals have a tubelike digestive system; one end of the tube serves as the mouth while the other end serves as the anus. This digestive system is called a **Complete Digestive System**. Food enters the mouth, passes through the long tube, and exits as feces through the anus.

The smooth muscles of the tubelike digestive organs move the food rhythmically through the system where it is broken down into absorbable forms. Outside of this tube are attached some accessory organs -- the liver, gall bladder, and pancreas -- which also help in the digestion of food. Figure 2 shows a comparison of the digestive systems of different representative species of animals.

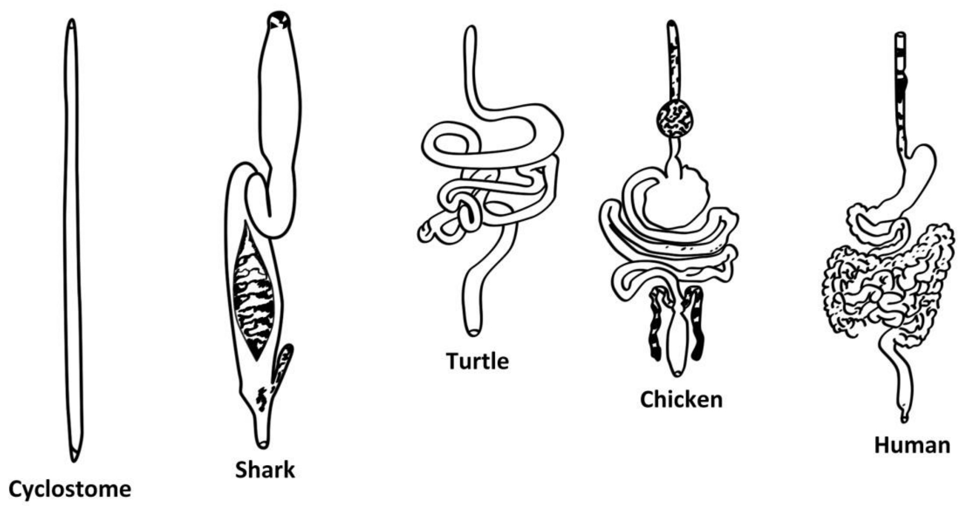


Figure 2. Digestive tracts of different representative species of animals.

Q4. In what ways are the different digestive systems of animals similar? In what ways are they different?

The more primitive animals like the *Hydra* have a 'digestive system' with only one opening (see Figure 3) which is also called an **Incomplete Digestive System**. These organisms eat and defecate with their mouth which also alternates as their anus!

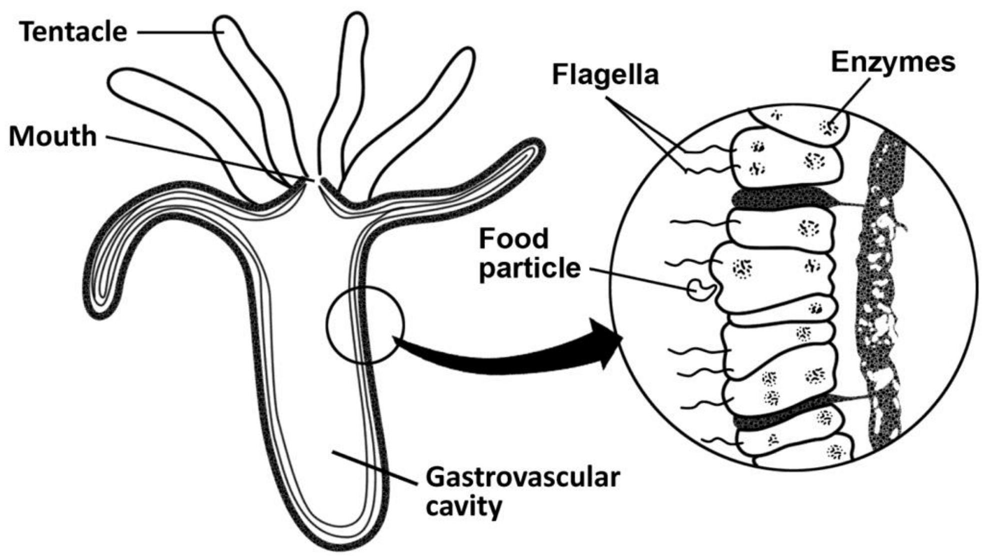


Figure 3. Hollow body of Hydra. The animal takes in food, digests food in its digestive cavity, and removes wastes through its mouth. Also shown is an enlarged part of the body wall.

Activity 1
Part 1B. A sweet break!

Objectives:

After performing this activity, you should be able to:

1. describe the process of mechanical digestion; and

2. explain how the physical breaking down of food helps in its digestion.

Materials Needed:

two 100 mL beakers or clear containers
warm water
two pieces of candies (hard candies)
mortar and pestle
paper towel

Procedure:

1. Fill the two beakers with warm water. Make sure that the amount of water placed in each glass is about the same. Label the glasses A and B.

2. Prepare two pieces of candies. Wrap a piece of candy in a paper towel and crush it using a mortar and pestle or any hard object like a piece of wood.

3. Place one piece of candy into the glass of warm water labeled *A* and place the crushed pieces of candy in the remaining glass of warm water labeled *B*.

4. Observe how long it takes for the whole candy in *Glass A* and the crushed pieces of candy in *Glass B* to dissolve.

5. Record your observation.

Q5. How does crushing the candy to smaller pieces affect its dissolution?

Q6. What does crushing the candy represent in the process of digestion?

Activity 2
How do enzymes affect digestion?

Objectives:

After performing this activity, you should be able to:

1. explain how enzymes affect digestion; and
2. infer chemical changes in food as it undergoes chemical digestion.

Materials Needed:

1 tablespoonful of granulated gelatin
10 mL fresh pineapple juice
10 mL bromeliad leaf juice
water
measuring cup
spoon
100 mL graduated cylinder
10 mL graduated cylinder
3 droppers
3 test tubes
test tube rack
markers
hot plate

Procedure:

1. Number and label the test tubes (1-water, 2-fresh pineapple juice, and 3-bromeliad leaf juice).

2. Prepare one tablespoonful of granulated gelatin in the measuring cup using 100 mL of boiling water.

3. Stir well with a spoon until the gelatin is dissolved.

4. Place 3 mL of water into test tube 1, 3 mL of fresh pineapple juice into test tube 2, and 3 mL of bromeliad leaf juice into test tube 3.

5. Add 10 mL of gelatin mixture to each test tube. Shake well to mix thoroughly.

6. Refrigerate the samples overnight.

7. On Day 2, check the contents of each test tube for solidification of the contents. Record your observations.

Table 1. Effect of enzymes on digestion

Test Tube	Contents	How do the contents of the test tube look like on Day 2?
1	Water and gelatin	
2	Fresh pineapple juice and gelatin	
3	Bromeliad leaf juice and gelatin	

Food undergoes physical and chemical change as it moves from one part of the gastrointestinal tract to the other. Digestion makes the nutrients found in food available to the different parts of the body for the organism's nourishment and overall wellness. In Activity 2, an enzyme called **bromelain** which is present in fresh pineapple juice and in bromeliad plants is used to demonstrate digestion of proteins.

Q7. How did bromelain affect the protein in gelatin?

Q8. Which of your observations show this effect?

Q9. There are other kinds of enzymes in your digestive system. How do these enzymes affect digestion?

Bromelain refers to a group of enzymes from bromeliad plants that break down proteins. They are proteases. Bromelain is found in both fresh pineapple and bromeliad leaf juices. This should not come as a surprise because pineapple is a bromeliad plant.

At certain times of the day, you hear your stomach rumbling. This is the sound you hear as the gastric juices are churned in an empty stomach. This indicates that you are already hungry and it is time for you to eat. The stomach and some glands start to produce gastric juices to prepare your stomach for the food you will eat. These gastric juices provide an acidic environment in the stomach. How do these gastric juices affect digestion in the stomach? In Activity 3, you will be introduced to the effect of pH on the digestion of food in the stomach and the intestine.

Activity 3
How does pH affect enzyme activity?

Objectives:

After performing this activity, you should be able to:

1. describe the process of chemical digestion; and
2. explain how enzymes act as catalyst during digestion.

Materials Needed:

1 tablespoonful of granulated gelatin
10 mL fresh pineapple juice
water
measuring cup
spoon
100 mL graduated cylinder
10 mL graduated cylinder
3 droppers
3 test tubes
test tube rack
markers
hot plate
1 M HCl
1 M NaOH

TAKE CARE! **Do not get any acid or base on your skin.**

Procedure:

1. Label the test tubes (A – acid, B – base, C – control <water>)

2. Prepare one tablespoonful of granulated gelatin in the measuring cup using 100 mL of boiling water.

3. Stir well with a spoon until the gelatin is dissolved.

4. Place 3 mL of pineapple juice into each of the labeled test tubes. Transfer 1 mL each of HCl, NaOH, and water into the corresponding test tubes of pineapple juice.

5. Transfer 10 mL of gelatin mixture to each test tube.

6. Using a spoon, stir the gelatin well until it dissolves completely.

7. Refrigerate the test tubes overnight.

8. On day 2, observe the contents of each test tube. Record your observations.

Table 2. Effect of pH on enzyme activity

Test Tube	**Contents**	**How do the contents of the test tube look like on Day 2?**
A	Acid added on gelatin with pineapple juice	
B	Base added on gelatin with pineapple juice	
C	Water added on gelatin with pineapple juice (Control)	

What is chemical digestion? Where does chemical digestion take place in the human digestive tract?

Q10. What role do the digestive enzymes have in digestion?

Q11. In which test tube did you observe the greatest amount of protein digestion?

Q12. In which test tube did you observe the least amount of protein digestion?

Q13. How do you explain your results?

Q14. Did your results support your hypothesis? Explain your answer.

Q15. In the human digestive tract, where is protein digested chemically?

Carbohydrates are broken down to simple sugars that are absorbed in the small intestines; they are circulated to the different parts of the body as they join the bloodstream. They are used up as sources of energy once they are assimilated by the cells; those that are circulated into the liver are stored.

Proteins are broken down to their component parts -- also called amino acids -- in the stomach. This process is aided by acids secreted by the cells that make up the walls of the stomach and enzymes that are present in the gastric juice. Like the simple sugars, amino acids are absorbed in the small intestine through the villi -- the fingerlike structures that line the walls of the small intestines -- and circulated to the different parts of the body. Those that are circulated into the liver are stored as glycogen.

In the case of **fats and lipids**, their digestion is completed in the small intestine where bile secreted from the liver disintegrates them into fatty acids and glycerol – particles that are circulated to the rest of the body and stored in fatty tissues.

Activity 4
A journey into the digestive system

Objectives:

After performing this activity, you should be able to:

1. Infer how the organs of the digestive system work together to carry out digestion of food and assimilation of nutrients; and
2. explain what happens to food as it gets digested.

Materials Needed:

Video clip: Journey of the digestive system
Link: http://www.youtube.com/watch?v=e3O1AdlC8bI

Writing materials

Procedure:

1. Your teacher will show a movie clip titled, *Journey of the Digestive System.*
2. Take down notes as you watch the movie clip.
3. On a separate sheet of paper, answer the following questions.

Q16. What does the movie clip say about the digestion of food?

Q17. What changes happened to the food as it was moved through the digestive tract?

Summary

Digestion starts when food is taken into the mouth. This is called ingestion. As you chew, you are breaking the food into small pieces as a means of mechanical breakdown. The pieces mix with saliva before you swallow. Saliva is a watery liquid made by the salivary glands. It softens and wets the food in the mouth and also initially starts chemical digestion through the enzymes present in it. Then the food passes through the esophagus. Muscle contractions in the esophagus help move the food down to the stomach. This process is called **peristalsis** (see Figure 4).

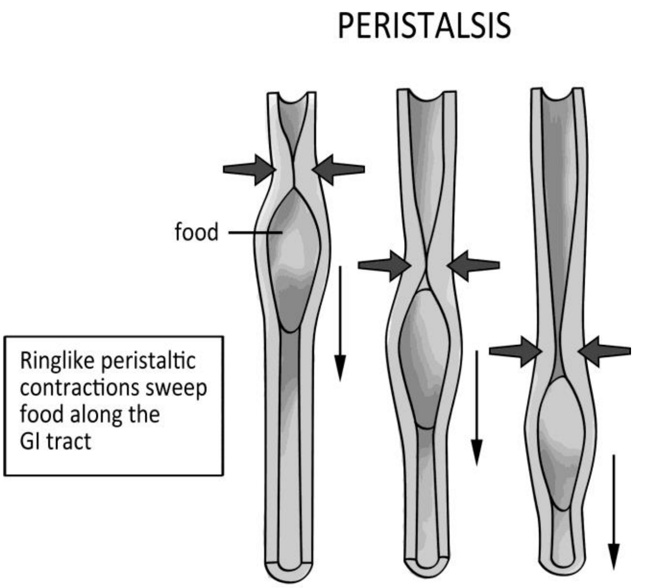


Figure 4. Peristalsis in the esophagus.

Stomach juices are chemicals made by the body that help digest food. The stomach is made up of muscles that churn and help mix the food and break it into even smaller pieces.

The digestive glands in the stomach lining produce acids and enzymes that digest proteins. These digestive juices could, in fact, harm the stomach. However, a thick mucus layer helps keep this acidic chemical environment from destroying the tissues of the stomach.

Digested molecules of food are absorbed through the small intestine. The walls of the small intestine contain many folds that are lined up with tiny fingerlike protrusions called villi. These villi are in turn covered with even smaller protrusions called microvilli. These structures increase the surface area through which nutrients are absorbed. During absorption, these nutrients pass through the walls of the intestine and into the bloodstream where they get transported to the different parts of the body.

The undigested parts of food or those that were not absorbed by the body are eliminated as feces. This process is called elimination or defecation. Figure 5 shows how food is changed to soluble forms as it is moved from one part of the digestive system to another.

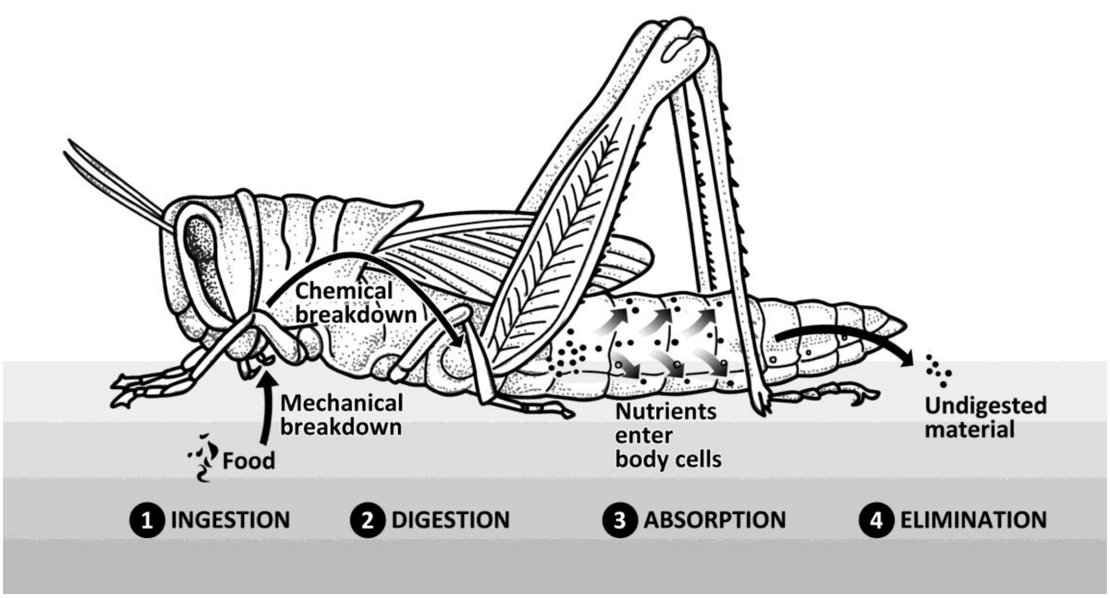


Figure 5. The process of digestion.

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Suggested time allotment: 2 to 3 hours

Unit 4
MODULE
4

NUTRITION AND WELLNESS

Overview

In the previous module, you have explored how the body obtains the nutrients it needs to fuel its activities. In addition to providing energy, our diet must also supply the raw materials needed for building complex molecules the body needs to grow, maintain itself, and reproduce.

In this module, you will survey the nutritional requirements of our body. This module will discuss nutrition and consider the choices we make that affect the proper functioning of the digestive system. This module will also consider how our diet and lifestyle contribute to the functioning of the human body as a whole.

> What are the nutritional needs of our body?
>
> What happens when the body's nutritional needs are not adequately met?

Your body needs food for energy, growth and repair, and as a source of substances for body processes. Different types of food provide different nutrients. How do you know if you are getting the right kind and amount of nutrients from the food that you eat?

Activity 1
Am I eating right?

Objectives:

After performing this activity, you should be able to:

1. make a record of your daily meals, and
2. determine if your food intake adequately meets nutritional requirements.

Procedure:

A.

1. Record in a Daily Meal Journal what you eat for three days. Table 1 shows a sample meal record for one day.

Table 1. Sample daily meal journal

Date	Meal	Food and Beverage	Amount
June 15	Breakfast	Rice	1 cup
		Tinapa	1 pc
		Fried egg	1 pc
		Water	1 glass
	Snack	Pandesal	2 pcs
		Water	1 glass
	Lunch	Rice	1 cup
		Ginisang munggo	½ cup
		Water	1 glass
	Snack	Boiled banana	1 pc
		Water	1 glass
	Dinner	Rice	1 cup
		Fried galunggong	1 pc
		Kamote tops	½ cup
		Water	1 glass

2. Interview your school nutritionist, school nurse, or barangay health worker on the kind and amount of food that you should eat to meet your nutritional requirements.

You should have gathered from your interview that you need to eat a variety of foods since no naturally occurring food has every nutrient. The Food and Nutrition Research Institute (FNRI) has developed a food pyramid for Filipinos, a simple and easy to follow daily eating guide. This guide is useful in helping people select food that supply all the nutrients for energy and growth.

Figure 1 shows a food pyramid which illustrates the recommended dietary allowance for teenagers.

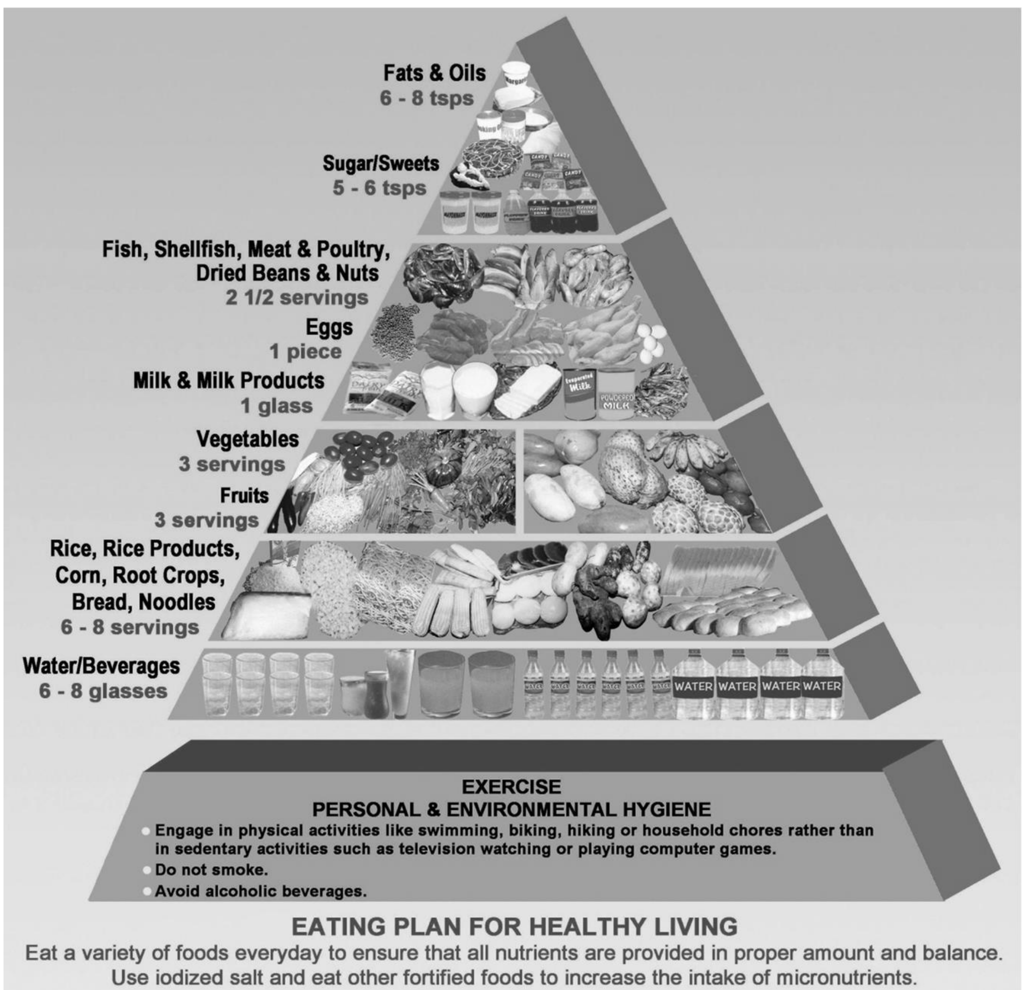

Figure 1. The Food Pyramid for teenagers recommends eating a variety of foods to ensure that all nutrients are provided in proper amount and balance. Source: Food and Nutrition Research Institute, Department of Science and Technology

Foods that contain the same type of nutrient belong to a food group. Foods have been divided into five groups – a) rice, rice products, corn, root crops, bread, noodles; b) fruits and vegetables; d) milk and milk products, eggs, fish, shellfish, meat and poultry, dried beans and nuts; and e) sugar and sweets, fats and oil. The recommended daily amount for each food group will supply your body with the nutrients it needs for good health.

3. Compare your entries in your daily meal journal with the recommended daily amount of servings.

An accurate meal journal tells a lot about your eating patterns. The Daily Meal Journal below belongs to a fourteen-year old named Conrad. Study his meal journal and answer the questions that follow.

Daily Meal Journal

Date	**Meal**	**Food and Beverage**	**Amount**
June 15	Breakfast	Rice	1 cup
		Tuyo	1 pc
		Water	1 glass
	Snacks	Yema	3 pcs
	Lunch	Rice	1 cup
		Fried tilapia	1 pc (medium)
		Water	1 glass
	Dinner	Rice	1 cup
		Fried chicken	1 pc
		Water	1 glass

Q1. Which food group in the Food Pyramid do you observe the greatest number of servings?

Q2. What did Conrad eat that belong to this food group?

Q3. Which food group/s do you see no servings?

Q4. Based on the Food Pyramid, how many servings from that group should Conrad have eaten?

Q5. What should Conrad include in his meals to ensure that he gets all the nutrients indicated in the Food Pyramid?

Daily Servings

For each day you should eat six to eight servings from the rice and rice products group, three servings from the vegetable group, three servings from the fruit group, one glass from the milk group, and two and a half servings from the fish and meat group. Only small amounts of sweets, fats, and oils should be consumed.

The size of a serving is different for different foods. For example, one cup of rice or 5 pieces of small pandesal is equivalent to one serving of the rice and rice products group. One piece medium-sized fish or 1/3 cup cooked dried beans is equivalent to one serving of the fish, meat and beans group. The table below shows the food groups, recommended intake, and equivalent of one serving portion of common foods.

Table 2. Food groups and the equivalent of one serving portion of common foods

Food groups	**Recommended intake**	**Equivalent of one (1) serving portion of common foods**
Fat and oils	6-8 teaspoons	1 teaspoon coconut oil (5 grams) = 1 tablespoon coconut cream = 1 teaspoon mayonnaise = 1 teaspoon margarine/butter = 2 teaspoons peanut butter
Sugar/sweets	5-6 teaspoons	1 teaspoon sugar (5 grams) = 1 teaspoon honey = 1 teaspoon fruit flavored drink (powder) = 2 teaspoons jam/jellies/preserves = 1/5 glass softdrink/flavored drink = 2-3 teaspoons fruit flavored drink (concentrate) = 1 piece hard candy
Fish, shellfish, meat & poultry, dried beans and nuts	2 ½ servings	1 serving = 1 piece medium size fish = 1/3 cup shellfish, shelled = 3 centimeters cube cooked pork/ beef/chicken = 1/3 cup cooked dried beans/nuts = ½ cup tofu = 1 piece tokwa = 1 slice cheese

Egg	1 piece	1 piece chicken egg
Milk and milk products	1 glass	1 serving = 1 glass whole milk = 4 tablespoons powdered whole milk diluted to 1 glass of water = ½ cup evaporated milk diluted to ½ glass of water
Vegetable	3 servings	1 serving of leafy vegetables = 1 cup raw or ½ cup cooked 1 serving of other vegetables = ½ cup raw or ½ cup cooked
Fruits	3 servings	1 serving of vitamin C rich food = 1 medium sized fruit or 1 slice of a big fruit 1 serving of other fruits = 1 medium sized fruit or 1 slice of a big fruit
Rice, rice products, corn, root crops, bread, noodles	6-8 servings	1 serving = 1 cup rice = 4 slices loaf bread = 2 slices puto = 5 pieces small pandesal = 1 cup corn = 2 cups noodle = 1 cup cooked yellow kamote

Source: http://www.fnri.dost.gov.ph

Take Home Activity:

1. Gather data on what local produce are available in your province and two nearby provinces. Research on the nutritional value of these local produce.

2. Tabulate the locally available food according to the categories in the Food Pyramid. Try to use local food produce in planning your meals.

Fiber

Although fiber cannot be digested and absorbed by the body, it plays an important role in cleaning the digestive tract. Fiber absorbs water and helps eliminate the waste products of the body. Fiber may help prevent certain diseases such as heart disease, cancer and diabetes. Not eating enough fiber can cause constipation and other intestinal problems. You should have just enough fiber in your diet as eating too much fiber can cause nutrients to pass through the system too quickly to be absorbed. Examples of some food that are rich in fiber are grains, fruits, and vegetables.

Water

Your body is made up of 55 to 60 percent water. Water plays important roles in important processes such as digestion, elimination of waste products, and regulation of body temperature. You need to drink about 8 glasses of water a day to replace the amount you lose through sweat, urine, and respiration.

Food Plate

Another tool in helping you monitor what you eat is the food plate (Figure 2). It is recommended that you should divide your food plate into four parts – the first part for grains like rice, corn, or bread, the second part for fruits, the third part for vegetables, and the fourth part for protein like meat or fish. Since vegetables differ in nutrient content, it is recommended that you eat a variety of vegetables each day. The most important thing to remember is to fill one-half of your plate with fruits and vegetables.

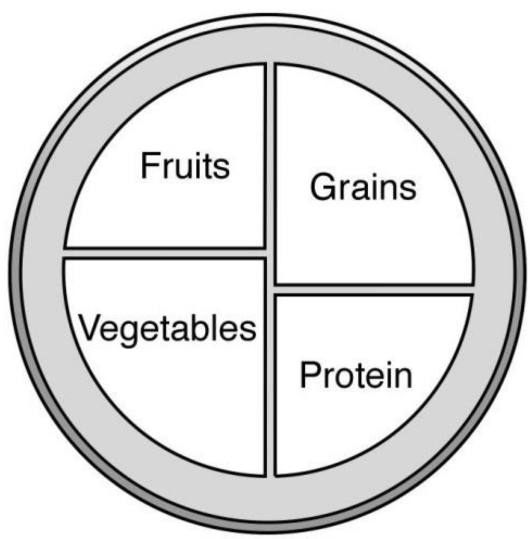

Figure 2. The Food Plate is divided into four parts as a general guide for how much a person should choose from each food group.

Activity 2
What happens when nutritional needs are not adequately met?

A good diet is important for proper growth and development and for the prevention of disease. A number of health problems and diseases are caused by a poor diet.

Objectives:

After performing this activity, you should be able to:

1. analyze the consequences of an unhealthy diet.
2. demonstrate understanding of diseases that result from nutrient deficiency and their prevention and treatment.

Procedure:

1. Using the table below as a guide, research on the sources of carbohydrates, protein, fats, vitamins and minerals, the functions of these nutrients, and the health problems that result when the requirement for these nutrients are not adequately met.

Nutrients	Food Sources	Functions	Deficiency signs and symptoms
Carbohydrates			
Protein			
Fats			
Vitamins and Minerals			

2. Present your output to the class.

Insufficient intake of nutrients can cause nutrition disorders. These disorders may cause health problems, especially in children, which may hinder growth and development.

Activity 3
Using essential concepts in nutrition to planning a menu

Objectives:

After performing this activity, you should be able to:

1. design a three-day menu that reflects balanced meals and provides the recommended daily allowance to an active teenager, and

2. incorporate local produce in your menu.

Procedure:

1. Design a three-day menu that reflects balanced meals and provides the recommended daily allowance to an active teenager.

2. Incorporate locally produced food products in your menu.

3. Present your output to the class.

Eating a variety of food increases the probability of getting the necessary nutrients that your body needs. Getting enough nutrients will result to proper growth and development and prevention of health problems. Learning how to meet your nutritional needs by making good food choices will help you become healthy.

References

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Suggested time allotment: 4 to 5 hours

Unit 4
MODULE
5

CELLULAR REPRODUCTION AND GENETICS

Overview

When you look at your parents, you can see features that you share with them, such as the shape of the eye, the presence of dimples, or even the hand you use when you write. The sharing of features can be explained by **heredity**, where traits are passed on from parents to offspring. Yet when you look at your brothers and sisters, even if you share the same parents, each one of you can be considered unique based on the combination of traits each possesses. That is **variation**, which demonstrates differences among individuals.

Genetics is the study of heredity and variation. It aims to understand how traits can be passed on to the next generation and how variation arises.

Every living thing undergoes reproduction. The nutrients taken by an individual will provide for energy for metabolic processes, for growth and development as well as reproduction. The cellular level of reproduction, in the form of **cell division**, provides for the backdrop for the organismal level of reproduction.

This module will differentiate the two types of cell division, **mitosis** and **meiosis**, as well as correlate heredity with the behavior of the **chromosomes** in the cell during meiosis. Investigations are included that will help you understand the mechanisms of heredity and the expression of traits.

What are the different types of cell division?

How are traits passed on to the next generation?

The Chromosome

All living things contain what we call the genetic material that serves as the set of instructions that direct the activities and functions of the cells. These genetic materials, also known as the **deoxyribonucleic acid** or **DNA**, are passed on from one generation to the next to ensure the continuity of life. In eukaryotic cells (cells with organelles), the DNA are bound with proteins and are organized as beads on strings to form **chromosomes** (Figure 1).

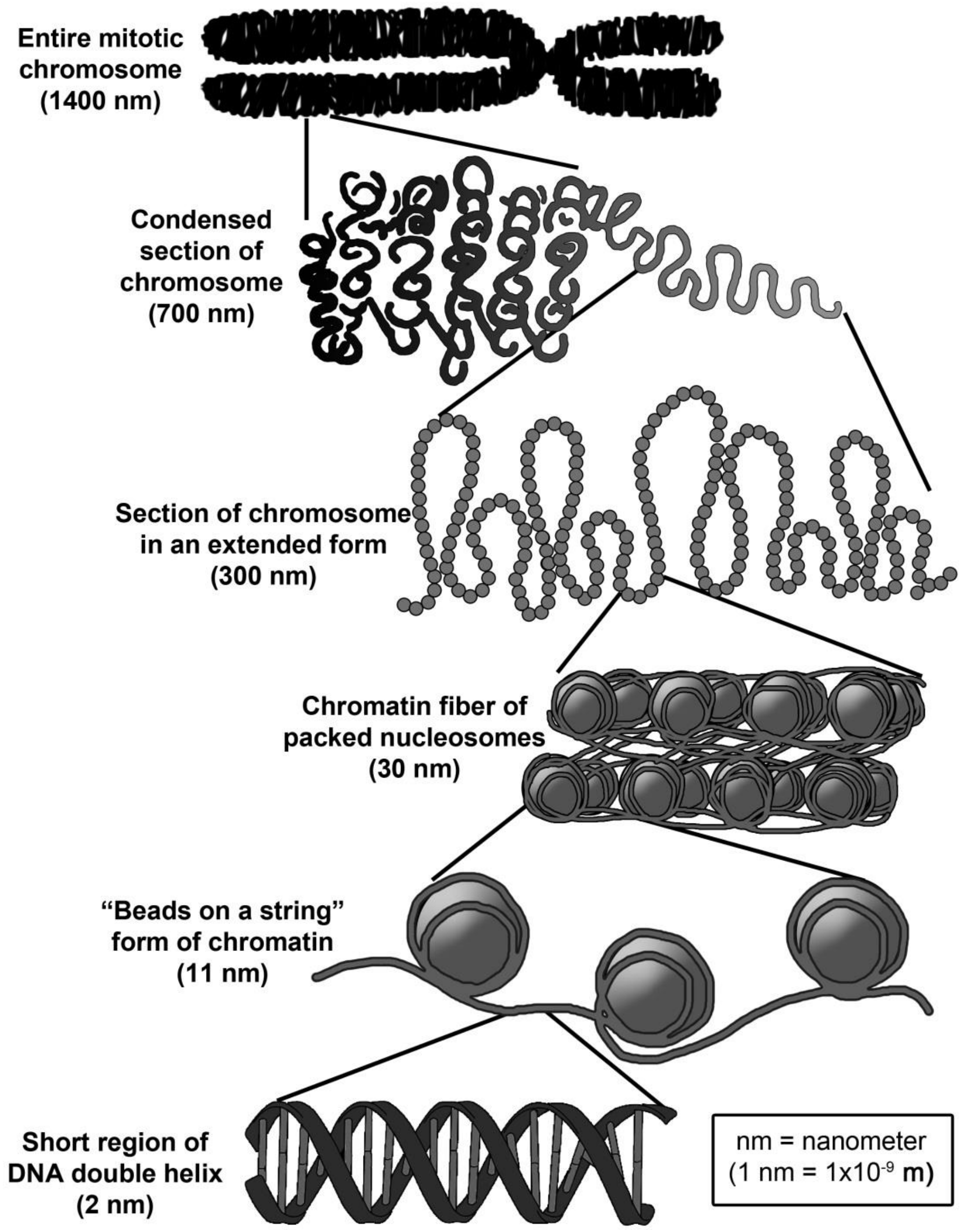


Figure 1.The organization of the DNA as genetic material.

The number of chromosomes in a cell is characteristic of the species to which it belongs. For example, humans have 46 chromosomes while rice have 12. Table 1 summarizes the chromosome numbers of some common organisms.

Table 1. Chromosome numbers of selected organisms.

Organism	**Chromosome number**
Saccharomyces cerevisiae (common yeast)	32
Caenorhabdites elegans (roundworm)	12
Drosophila melanogaster (fruit fly)	8
Canis lupus familiaris (dog)	52
Homo sapiens (man)	46
Arabidopsis thaliana (mouse ear cress)	10
Oryza sativa (rice)	24
Zea mays (corn)	20

The Cell Cycle

The chromosomes of a cell change form as the cell transitions from one stage to another in a typical cell cycle. The cell cycle may be divided into two stages: the **interphase** where the chromosomes are long and extended and are also referred to as **chromatin**, and the **cell division** phase where the chromosomes become condensed or thickened (Figure 2).

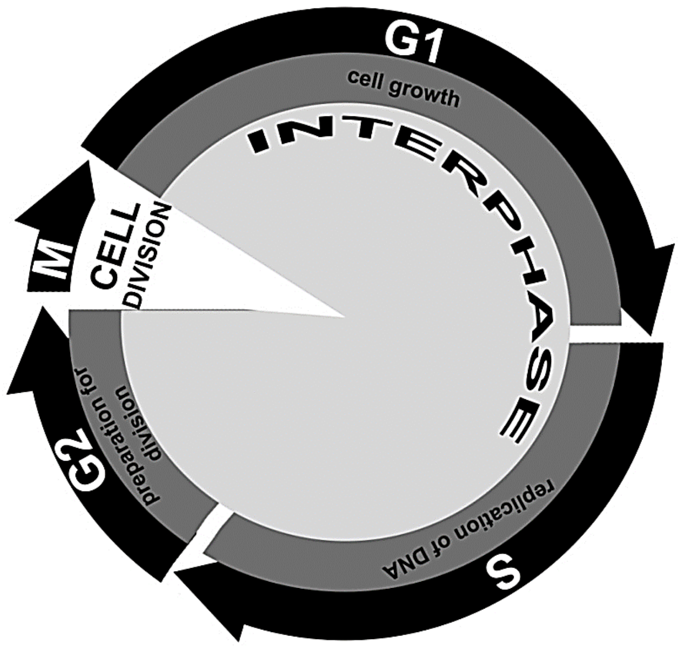


Figure 2. The cell cycle.

The interphase refers to the period that follows one cell division and precedes another. During this stage, the cell does not divide; it merely grows. The chromosome doubles or replicates itself because the DNA molecule contained in the chromosome produces an exact copy of itself.

The interphase is divided into three substages. The stage from the formation of a new cell until it begins to replicate its DNA is called the first gap period or **G_1,** during which time the cell grows initially. This stage is characterized by protein and ribonucleic acid (RNA) synthesis. RNA, which is synthesized based on the DNA, is then used to synthesize proteins.

The middle stage of interphase, called the synthesis stage or **S**, is the period of DNA synthesis or replication. The chromosomes are duplicated in preparation for the next cell division. The second gap period or **G_2,** falls between the S period and the next cell division or **M** (mitosis or meiosis, see discussion below) phase. G_2 represents a period of rapid cell growth to prepare for cell division.

During interphase, the nucleus is clearly visible as a distinct membrane-bound organelle. In stained cells, this membrane can be clearly seen under the light microscope. One or more nucleoli are visible inside the nucleus. On the other hand, the chromosomes cannot be clearly seen. They appear as an irregular mass that is grainy in appearance because the DNA they contain are stretched out thinly in the nucleus. This facilitates the replication of DNA during the S phase.

Cell Division

Alternating with the interphase is the cell division phase. In eukaryotic cells, there are two types of cell division: **mitosis** and **meiosis**.

1. Mitosis

This type of cell division produces two identical cells with the same number of chromosomes. Mitosis is divided into four stages.

STAGE A: Prophase. The nuclear membrane and nucleoli may still be present. The chromosomes are thicker and shorter because of repeated coiling. At this stage, each chromosome is made up of two identical sister **chromatids** as a consequence of replication of DNA during the S phase. The two chromatids produced from one chromosome are still attached at one point, called the **centromere**. The centromere may divide the chromosome into the shorter arms, also called the **p arms** (‘p’ stands for *petite* in French) and the longer **q** arms. If the chromosomes are stained using Giemsa, alternating dark and light regions will appear. These are the **heterochromatin** and **euchromatin**, respectively. The heterochromatin are more coiled and dense than the euchromatin (Figure 3).

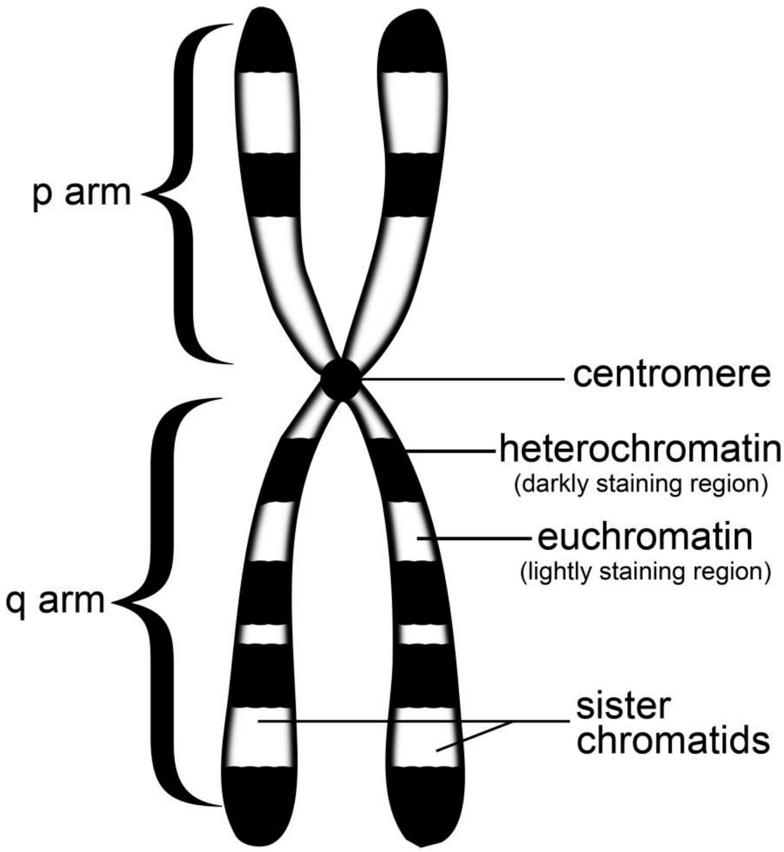


Figure 3. Parts of the chromosome.

STAGE B: Metaphase. The nuclear membrane has disappeared while the highly coiled chromosomes align at the metaphase plate, an imaginary plane equidistant between the cell's two poles. Spindle fibers are also formed. Each fiber binds to a protein called the **kinetochore** at the centromere of each sister chromatid of the chromosome.

STAGE C: Anaphase. The paired centromeres of each chromosome separate towards the opposite poles of the cells as they are pulled by the spindle fibers through their kinetochores. This liberates the sister chromatids. Each chromatid is now regarded as a full-fledged chromosome and is only made up of one sister chromatid.

STAGE D: Telophase. The chromosomes are now at the opposite poles of the spindle. They start to uncoil and become indistinct under the light microscope. A new nuclear membrane forms around them while the spindle fibers disappear. There is also **cytokinesis** or the division of the cytoplasm to form two separate daughter cells immediately after mitosis.

Activity 1
Observing mitosis

Objectives:

After you have performed this activity, you should be able to:

1. identify the different stages of mitosis in plant and animal cells, and
2. differentiate plant and animal mitoses.

Materials:

Prepared slides of onion root tip and white fish blastula
Compound microscope

Procedure:

1. Examine the onion root tip and white fish blastula slides under the microscope. Based on the descriptions provided in the previous section, identify and draw from each slide the following: **interphase, prophase, metaphase, anaphase,** and **telophase.** Cells do not divide at the same time. Therefore, you will find cells at different stages of mitosis. With the LPO, locate and study the cells at these stages, then switch to the HPO to study the chromosomes in detail.

2. Locate the **centrioles** at opposite sides of a mitotic cell. These form star-like structures called **asters** at the poles of the spindles.

Q1. Where can you find these centrioles, in plant cells or animal cells?

3. Detect the presence of cleavage furrows in the mitotic cell of the white fish blastula. Cleavage furrows grow inward in the cell membrane until the cell is divided into two.

Q2. Do you also find a cleavage furrow in mitotic plant cells?

2. Meiosis

The number of chromosomes normally remains the same within the species. It does not double or triple for every generation. This suggests that a different kind of cell division must take place in an individual. This kind of cell division is called **meiosis,** from a Greek word which means “to make smaller.” Meiosis reduces the chromosome number in half. It takes place in plants and animals whenever **gametes**, or sex cells, are formed through the process called **gametogenesis**.

Meiosis is a special type of cell division where the cell undergoes two rounds of cell division to produce four daughter cells, each with half the chromosome number as the original parent cell and with a unique set of genetic material as a result of exchange of chromosome segments during the process of **crossing over**.

The first round of meiotic division, also known as **meiosis I**, consists of four stages: **prophase I, metaphase I, anaphase I**, and **telophase I**. Prophase I of meiosis I, unlike its counterpart in mitosis, is more elaborate and should be understood well in order to grasp the mechanisms of heredity.

STAGE A: Prophase I. Meiosis starts with this stage and includes the following sub-stages:

Leptotene*.* Each chromosome is made up of two long threads of sister chromatids as a result of replication during the S phase of the cell cycle.

Zygotene*.* The chromosomes begin to pair off. Pairs of chromosomes are called **homologous** chromosomes, and this pairing process is exact.

Pachytene*.* The chromosomes contract due to repeated coiling. **Crossing over** takes place during this stage where a segment of a sister chromatid of one chromosome is exchanged with the same segment of the sister chromatid of the homologous chromosome through the formation of a cross-linkage of the segments called a **chiasma** (Figure 4). After crossing over, the sister chromatids of each chromosome may no longer be identical with each other based on the genetic material they contain.

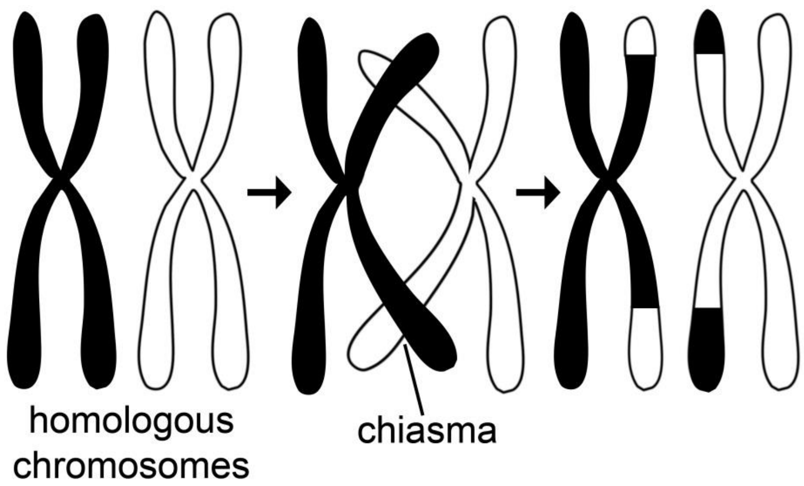


Figure 4. Crossing over of homologous chromosomes during meiosis I.

Diplotene*.* The chromosomes begin to uncoil.

Diakinesis*.* The paired chromosomes disperse in the nucleus.

STAGE B: Metaphase I. The paired chromosomes arrange themselves along the equatorial plate.

STAGE C: Anaphase I. Spindle fibers form and attach to the centromeres of the chromosomes. The homologous chromosomes separate from each other completely and start their movement toward the poles of the cells as they are pulled by the spindle fibers. As the centromere of each chromosome does not divide, the sister chromatids remain together.

STAGE D: Telophase I. This is the stage when the chromosomes reach their respective poles. Cytokinesis follows and two daughter cells are formed. Each cell now has only half the chromosome number because only one chromosome from each pair goes to the daughter cell. This is called the **haploid** condition, in contrast to the **diploid** condition at the beginning of meiosis I where each chromosome pair is intact. Telophase I is followed by **interphase II**.

Note that each chromosome still has two sister chromatids; it is therefore necessary for the cells to undergo another round of division.

The second meiotic division, also known as **meiosis II**, is mitotic in nature and consists of the following stages: **prophase II**, **metaphase II**, **anaphase II** and **telophase II**; these stages are identical with the mitotic stages. The results are four cells, two from each daughter cell from meiosis I, with one half the diploid chromosome number and with only one sister chromatid for each chromosome.

Figure 5 shows the different stages of meiosis in the squash anther.

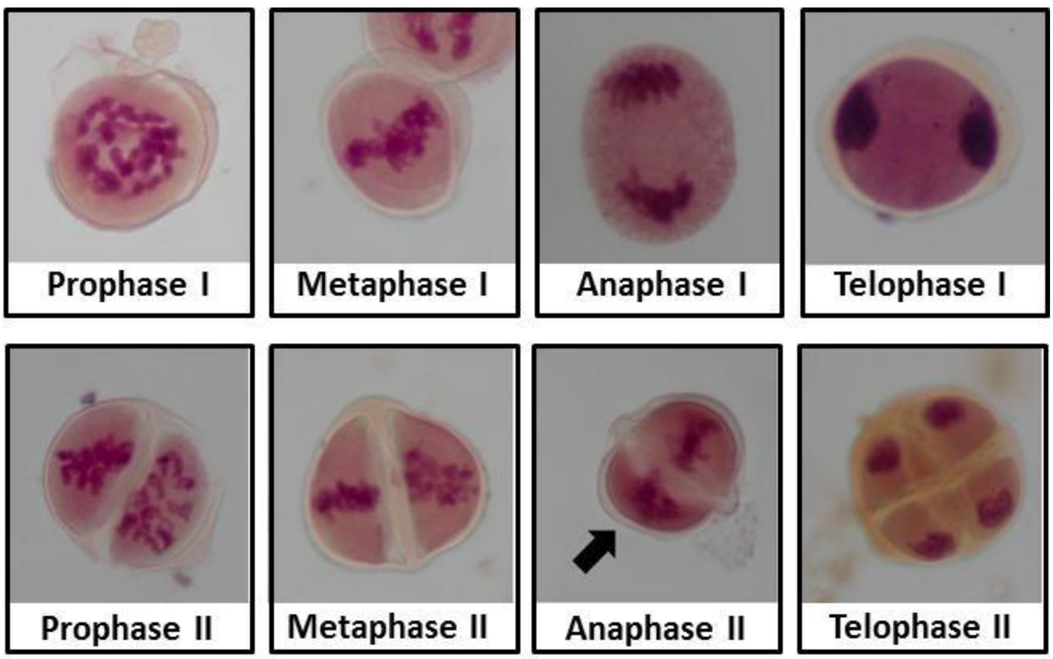


Figure 5. Stages of meiosis in the squash anther.

Activity 2
Comparing mitosis and meiosis

Objective:

By the end of the activity, you should be able to differentiate mitosis from meiosis.

Procedure:

Complete the table below.

	Mitosis	Meiosis
Number of daughter cells produced		
Number of chromosomes is halved. (Yes/No)		
Pairing of homologous chromosomes take place. (Yes/No)		
The daughter cells produced are always identical in terms of genetic material. (Yes/No)		

Role of Meiosis in Gametogenesis

Gametes such as eggs and sperms unite during fertilization, forming a diploid zygote. The zygote has one set of chromosomes from the male parent and another set from the female parent. In humans, both father and mother contribute 23 chromosomes each through their gametes. Thus, the zygote has 46 chromosomes. The zygote divides many times. This produces a new diploid multicellular organism.

Sperm cells are produced in the testes of male animals. Meiosis produces four cells which are very small but of similar size. These cells become **spermatozoa** (singular form is **spermatozoon**) or sperms. The nucleus is found in the head of the sperm; mitochondria are found at the midpiece that connects the head to the tail. These mitochondria provide the energy for the movement of the sperm’s tail.

In female animals, egg cells are produced in the ovary. When a cell in the ovary undergoes meiosis, new cells which differ in size are produced. After meiosis I, two cells – one big and one small – are produced. Meiosis II produces one big and one small cell from the first big cell. The small cell produced from meiosis I may or may not divide. If it does, two small cells are produced. The big cell becomes the egg cell; the small cells disintegrate. The egg cell contains a lot of stored food which is used by the growing embryo at the start of its development. In fertilization, the tiny sperm cell only contributes its genetic material found in the head. Figure 6 summarizes the formation of gametes.

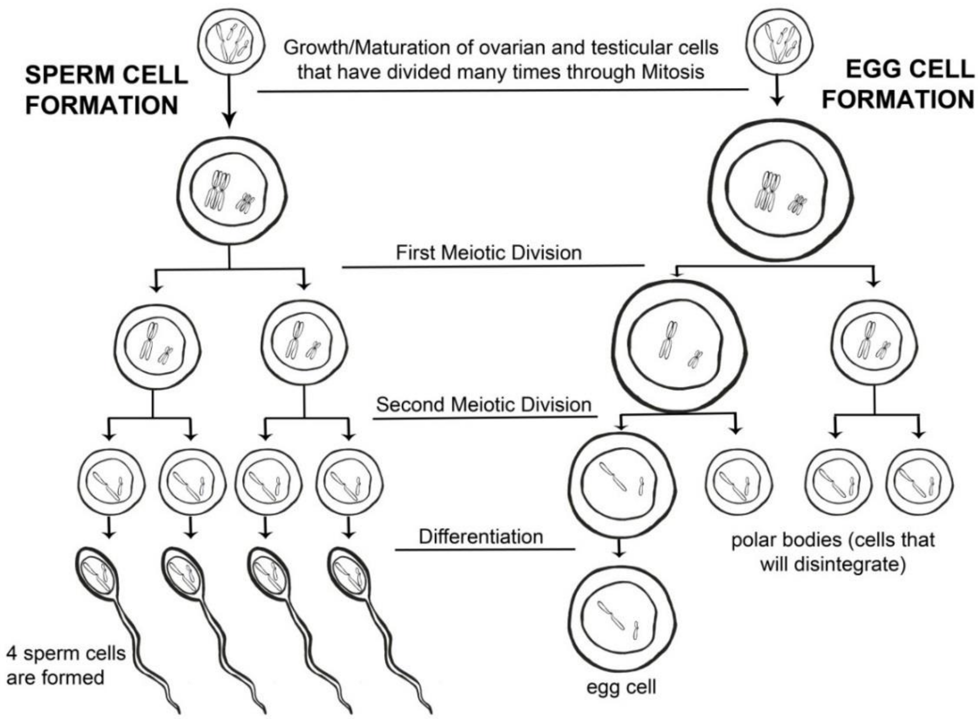


Figure 6. Gametogenesis in the testis and ovary of animals.

When Something Goes Wrong During Meiosis

Meiosis may not always proceed normally. Accidents sometimes happen. These accidents may affect the functioning of the spindle fibers or the movement of one or more chromosomes. In humans, some accidents have been known to cause abnormal conditions. For example, when chromosomes in a pair fail to separate from each other during Meiosis I, the resulting gamete acquires both members of a pair of chromosomes. If this involves chromosome pair 21, for example, and one of the gametes contains two copies of the chromosome, then the individual produced will have 47 chromosomes in his or her cells (with three copies of chromosome 21). This condition is known as **Down's syndrome**, named after Dr. Langdon Down who first studied the condition. The extra chromosome 21 will lead to an imbalance of genetic material in the cell. People with this condition suffer from variable degrees of mental retardation, sterility, and increased risk beyond the age of 40 of Alzheimer's disease, which affects the functioning of the brain. Down's syndrome is usually associated with pregnancy in women above 35 years of age.

Sometimes, a piece of chromosome breaks off and gets lost. The effects of this accident depend on the particular genetic material lost. For example, when a part of chromosome 5 is lost, the afflicted individual will have a face that is round, moonlike, cries feebly and is mentally and physically retarded. This condition is called **Cri du chat syndrome**; cri du chat is French for cat's cry, which is the sound a baby with this condition makes when he/she cries.

Several drugs may cause breaks or other abnormalities in the chromosomes. Chlorpromazine (a popular tranquilizer), diphenhydramine (an antihistamine), and lysergic acid diethylamide or LSD (a hallucinogen) are some drugs known to cause breaks in the chromosomes.

Mendelian Genetics

How is the behavior of the chromosomes during meiosis related to heredity? In order to answer this question, we must first look back at the experiments of Gregor Mendel. The results of his garden experiments laid down the foundations of Modern Genetics.

Mendel's Discovery of the Principles of Heredity

Gregor Mendel was an Augustinian monk in a monastery in Brünn, Austria-Hungarian Empire (now Brno, Czech Republic). He was interested in investigating how individual traits were inherited. He wanted to find out whether both parents contributed equally to the traits of the offspring. He also wanted to know if the traits present in the offspring were produced by the blending of the traits of the parents.

Mendel chose the garden pea (*Pisum sativum*) for his experiments. Before he started his experiments, Mendel first produced pure-breeding plants. Mendel allowed his pea plants to self-pollinate for many generations until all the offspring had the same features as the parents, generation after generation.

When he has pure-breeding plants, Mendel began cross-pollinating peas with contrasting traits. The pure-breeding peas constituted the **parental** or P_1 **generation**. All offspring of these crosses resembled one another. For example, when he crossed pea plants that produced round seeds with pea plants that produced wrinkled seeds, all the offspring had round seeds.

The offspring of the parental cross are called the **first filial** (F_1) **generation**. In Mendel's experiments, the F_1 generation are also called **hybrids** because they resulted from a cross between two pure-breeding plants with contrasting traits (for example, pea plants with round seeds crossed with pea plants with wrinkled seeds). Table 2 shows the seven pure-breeding crosses that he made based on seven characters of the plant and the resulting traits of the F_1 generation.

Table 2. Results of Mendel's crosses between pure-breeding pea plants

Characters Studied	**Parents**		**First Filial (F_1) Generation**
Seed shape	Round	Wrinkled	Round
Seed color	Green	Yellow	Yellow
Seed coat color	Colored	White	Colored
Pod shape	Inflated	Constricted	Inflated
Pod color	Green	Yellow	Green
Flower position	Axial	Terminal	Axial
Stem length	Long	Short	Long

When the plants from the F_1 generation were crossed with each other or self-pollinated, the offspring (F_2 or **second filial generation**) were of two types.

For example, Mendel counted 5,474 round seeds and 1,850 wrinkled seeds in the F_2 generation. Note that the round seeds were about three times as many as the wrinkled seeds. The ratio of round seeds to wrinkled seeds was 2.96:1 or nearly 3:1. Moreover, the wrinkled seed type did not appear in the F_1 generation. Table 3 summarizes the results on Mendel's second set of experiments.

Table 3. Results of Mendel's crosses between hybrid plants

Characters Studied	Hybrid	F_2 Generation Produced by Self-Pollinating F1 Hybrids		Observed Ratio
Seed shape	Round	Round	Wrinkled	2.96:1
Seed color	Yellow	Green	Yellow	3.01:1
Seed coat color	Colored	Colored	White	3.15:1
Pod shape	Inflated	Inflated	Constricted	2.95:1
Pod color	Green	Green	Yellow	2.82:1
Flower position	Axial	Axial	Terminal	3.14:1
Stem length	Long	Long	Short	2.84:1

Based on the results of his experiments, Mendel hypothesized that there was a factor in the plants which controlled the appearance of a trait. These factors are what we call **genes** today.

Since two alternative expressions of a trait (e.g., round or wrinkled seed) were possible, he hypothesized that traits were controlled by a pair of genes, now called **alleles**. Mendel's first hypothesis was: *in each organism, there is a pair of factors which controls the appearance of a particular trait*.

Mendel noted that for each trait he studied, there is one trait that dominates the other. Based on the results for the F_1 generation, the trait for round seeds is the **dominant trait**. The trait of wrinkled seeds, which did not appear in the F_1 generation, is called the **recessive trait**. Its appearance was either prevented or hidden by the dominant trait. This is now known as the **principle of dominance**: *The dominant trait dominates or prevents the expression of the recessive trait*. Today, dominant and recessive traits are represented by a capital and a small letter, respectively. A dominant trait like round seed, for example, is represented by letter *R* and a recessive trait like wrinkled seed is represented by a small letter *r*. Since genes occur in pairs, a pure-breeding round-seed plant is symbolized as *RR* and pure-breeding wrinkled-seed pea plant as *rr*. Table 4 shows the dominant and recessive traits of peas studied by Mendel.

Table 4. Dominant and recessive traits in *Pisum sativum* (Garden Pea)

Characters Studied	Dominant Trait	Recessive Trait
Seed shape	Round	Wrinkled
Seed color	Yellow	Green
Seed coat color	Colored	White
Pod shape	Inflated	Constricted
Pod color	Green	Yellow
Flower position	Axial	Terminal
Stem length	Long	Short

Law of Segregation

Before Mendel's time, it was believed that all traits become mixed when they are transmitted from generation to generation, as red and blue paints mix to give a violet color. However, when Mendel crossed pure-breeding pea plants, the pea plants did not produce offspring with blended or intermediate traits.

In Mendel's experiments, the pure-breeding parent plants had two identical genes for a trait: round seed = *RR*, wrinkled seed = *rr*. Mendel hypothesized that: *The pair of genes segregate or separate from each other during gamete formation*. This is now known as the **Law of Segregation**.

Genes and Gametes

Following Mendel's reasoning, a pure-breed, round-seeded parent plant has an allelic combination or **genotype** of *RR* while a pure-breed, wrinkled-seeded parent plant has a genotype of *rr*. Individuals that are pure-breeding for a particular character therefore have identical alleles. These individuals have a **homozygous** genotype. For seed shape, a homozygous dominant individual will produce round seeds while a homozygous recessive individual will produce wrinkled seeds.

Mendel's law of segregation states that the genes of a pair, for example *RR*, separate during gamete formation. One gene goes to one gamete, while the other gene goes to another gamete. Since the genes of this pair are alike, all the gametes produced by this homozygous parent will be alike. All have gene *R*. The same is true for the other parent. All its gametes will have gene *r*. (See Figure 7.)

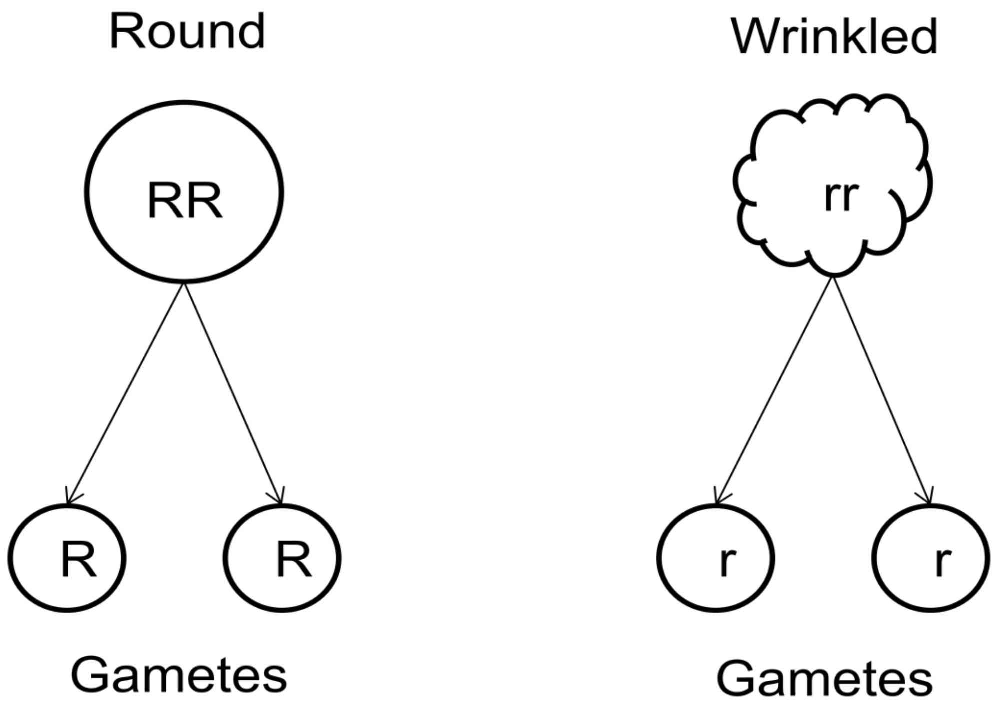


Figure 7. Gamete formation of pure-breeding round- and wrinkled seed-bearing pea plants.

Now recall what we have learned in meiosis. During anaphase I of meiosis I, the chromosome pairs separate and move to opposite poles. Now remember that a trait is governed by a pair of alleles. Each allele is found in a chromosome of a chromosome pair. In other words, the chromosomes serve as vehicles for these alleles. So when these chromosomes segregate during anaphase I, the alleles they carry also segregate. This becomes the chromosomal basis of Mendel’s first law (see Figure 8).

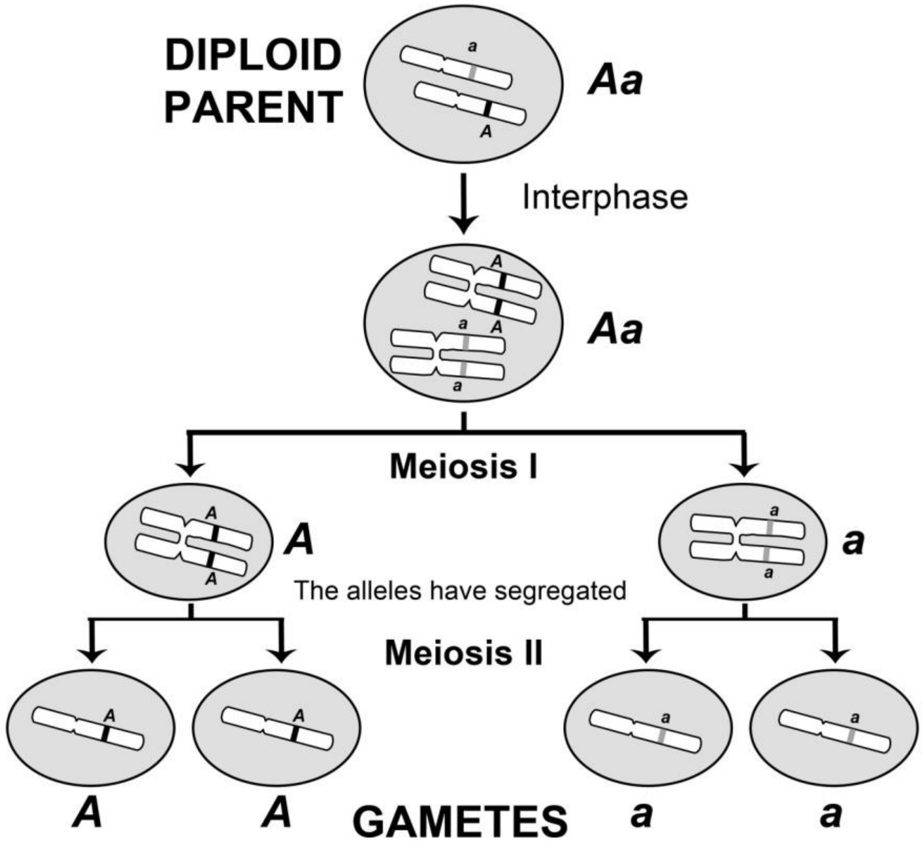


Figure 8. Chromosomal basis of Mendel's Law of Segregation.

At fertilization, when the gametes formed during gametogenesis by *RR* and *rr* plants unite, all the zygotes will have the genotype *Rr* (Figure 9). Thus, all the F_1 plants will have a genotype of *Rr*. An individual with contrasting alleles (a dominant and a recessive allele) for a particular character is said to have a **heterozygous** genotype. However, *Rr* individuals will still produce round seeds because of the presence of the dominant allele *R*. These will be just as round as all the seeds produced by the *RR* parents. The expression of the genotype of an individual for a particular character is referred to as its **phenotype**.

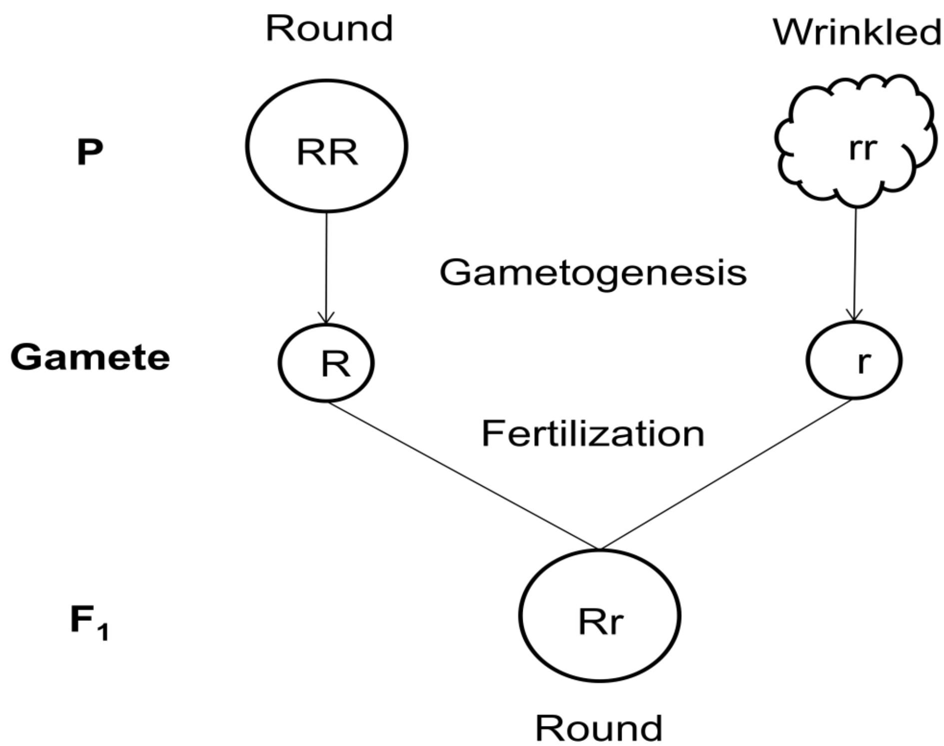


Figure 9. The result of crossing pure-breeding round and wrinkled seeds.

Knowing the Genotype

When you observe a pea plant, you can easily see the plant's yellow pods or its axial flower. By simply looking at the plant, you can immediately tell a plant's phenotype. However, you cannot always tell its genotype. For instance, a plant with wrinkled seeds certainly has a *rr* genotype. But what about a plant with the dominant trait, round seed? Its genotype could either be *RR* or *Rr.* There is, however, a way of knowing whether the plant is homozygous or heterozygous for a given character. Mendel applied two techniques in determining the genotype of a pea plant. These are **self-fertilization** and **testcross techniques**.

1. Self-fertilization Technique

When self-fertilized, homozygotes always produce pure-breeding plants. Thus, round-seeded peas will breed only round-seeded peas. What about heterozygotes? Look at Table 3 again. Heterozygous round F_1 peas produce round and wrinkled seeds in the ratio three round seeds to one wrinkled seed. This ratio (3:1) is called a **phenotypic ratio**.

Self-fertilization enables us to determine whether an individual is homozygous or heterozygous for a given trait by observing the phenotype(s) of its offspring. Homozygotes are pure-breeding. Heterozygotes produce two kinds of offspring; three out of four offspring show the dominant trait and one out of four excessive the recessive trait.

2. Testcross Technique

Testcross involves a cross between the recessive parental type (*rr* in our sample cross) and the individual with the dominant trait but with unknown genotype. You will observe in Figure 10 that homozygote dominants, when crossed with recessives, produce only one kind of offspring and all exhibit the dominant trait. Heterozygotes, on the other hand, when crossed with recessives, produce two kinds of offspring. About one-half of the offspring show the dominant trait while the other half exhibit the recessive trait.

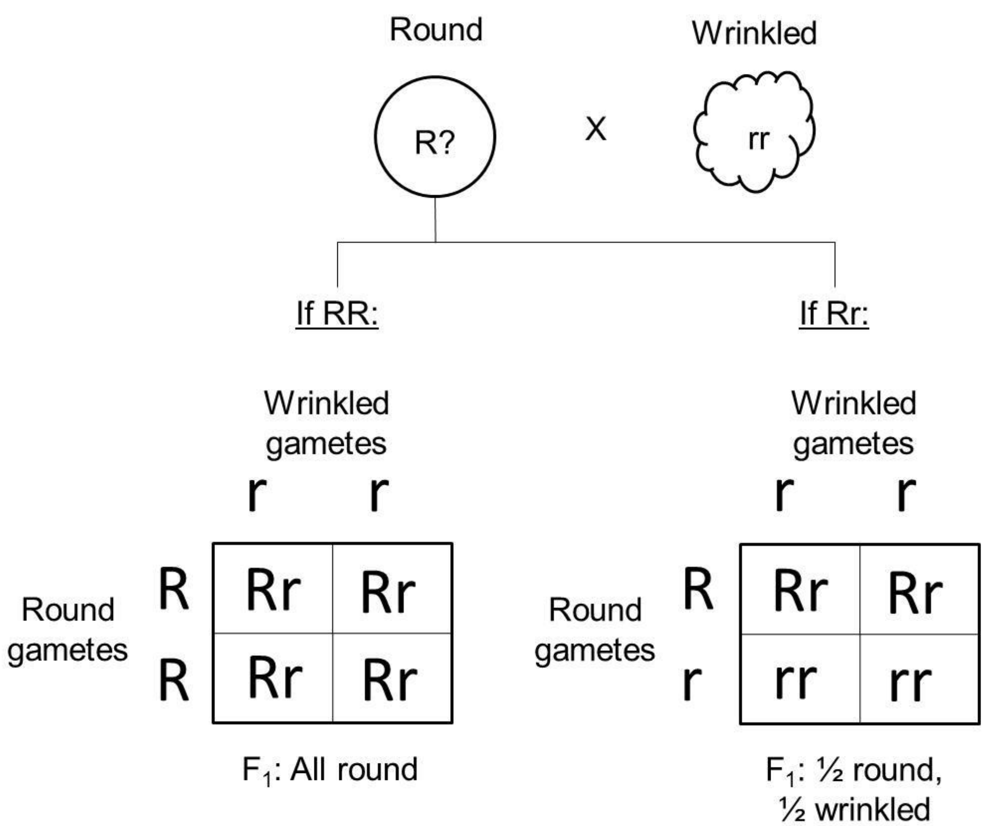


Figure 10. Testcross technique.

Probability

Chance plays a role in the inheritance of a trait. During fertilization, the union of a male gamete with gene *R* and a female gamete with gene *r*, for instance, happens by chance. During meiosis, the assortment of the different chromosomes also occurs by chance. Activity 3 illustrates the role of chance in the inheritance of a trait.

Activity 3
Tossing coins and probability

Objective:

After performing this activity, you should be able to predict the outcomes of crosses based on the principle of probability.

Materials:

2 coins, a piece of paper, and a pencil or pen

Procedure:

1. On a piece of paper, make a chart similar to the one given below.

	Head (H)	**Tail (h)**
Total		
Percentage		
Ratio of the combinations		

2. Toss a coin. If a head comes up, mark column 1; if a tail, then mark column 2. Make 50 tosses of the coin.

3. Get the total number of times each face of the coin appears. Calculate the percentage of the appearance of each face. To compute the percentage:

(*total* / 50) x 100 %

Q1. What is the ratio of heads to tails?

4. Let us assume that the coin represents the genotype of a parent, and each face is an allele, with the head as the dominant allele (H) and the tail as the recessive allele (h).

Q2. What is the ratio of the gametes of this parent with heterozygous genotype?

5. On the same piece of paper, make a chart similar to the one given below.

	Head-Head (HH)	**Head-Tail (Hh)**	**Tail-Tail (hh)**
Total			
Percentage			
Ratio of the combinations			

6. Toss the two coins together. If a head-head combination appears, mark column 1; if head-tail, mark column 2; and if tail-tail, mark column 3. Make 50 tosses of the coins.

7. Get the total number of times each combination appears. Calculate the percentage of the appearance of each combination. To compute the percentage:

$$(\textit{total} / 50) \times 100\ \%$$

Q3. What is the ratio of a head-head, head-tail, and tail-tail combination when you make 50 tosses?

Q4. If you toss the same coins in 100,000 times, would you approximately get the same ratio?

Q5. Let the head (H) represent a dominant gene and the tail (h), a recessive gene. Compare the ratio you obtained in this activity with the one obtained by Mendel in his monohybrid F_2 generation peas (see Table 3). Are they approximately similar?

Diagramming a Cross

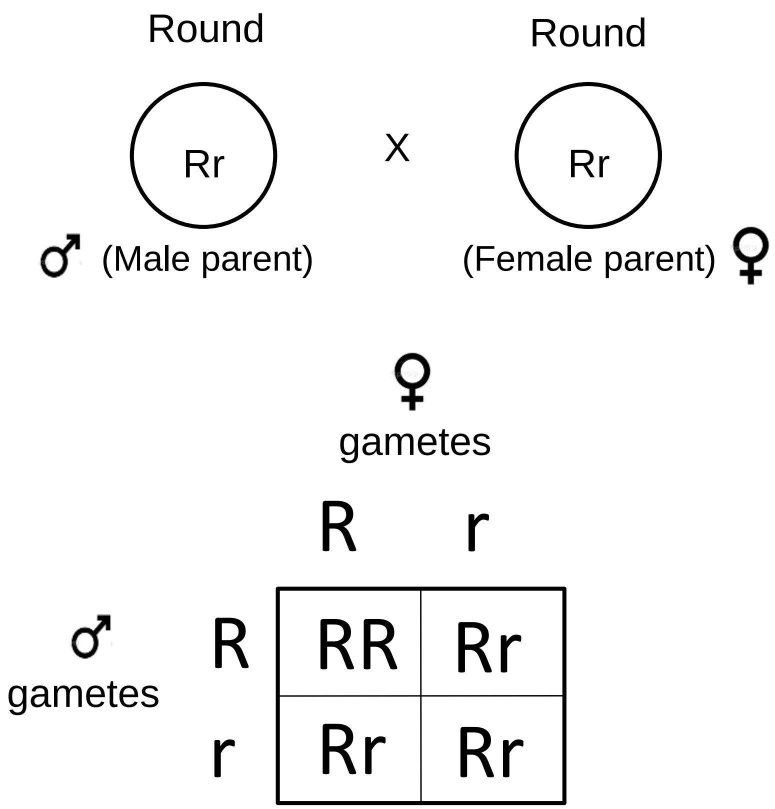
Mendel's crosses can be recorded in a chart called a **Punnett square**. The Punnett square helps us to predict the outcome of a given cross. It allows us to determine the possible combinations of genes in a cross.

The use of the Punnett square can be best illustrated by solving an actual problem, like determining the expected result when two hybrid round-seeded peas are crossed. From previous discussions, you know that the expected phenotypic ratio from this cross is 3:1. This time, we will determine the expected genotype of the offspring.

Figure 11 diagrams the steps in making a Punnett square. From the finished square, you can tell the genotypes of the offspring in the given cross.

Look at Figure 11. How many kinds of genotypes are possible in this cross? What are these genotypes?

Since a zygote with a genotype *Rr* is shown twice in the Punnett square in Figure 11, the chance or probability that a zygote will have an *Rr* genotype is two out of four (2/4 or 50%). One out of four (1/4 or 25%) will have a genotype of *RR* while one out of four will have a genotype of *rr*. Therefore, the genotypic ratio in the given cross is one *RR* (homozygous round seed) to two *Rr* (heterozygous round seed) to one *rr* (homozygous wrinkled seed). The genotypic ratio is simply written as 1:2:1. This 1:2:1 ratio is what you should have obtained as your ratio in Activity 3.



Genotypic Ratio: ¼ RR: ½ Rr: ¼ rr

Phenotypic Ratio: ¾ round: ¼ wrinkled

Figure 11. Punnett square method to solve a hybrid cross.

Activity 4
Comparing genotypic and phenotypic ratios for a typical Mendelian trait

Objective:

After performing this activity, you should be able to solve for the phenotypic and genotypic ratios of any given cross.

Procedure:

Let *D* = dominant allele and *d* = recessive allele, while *DD*, *Dd*, and *dd* represent the homozygous dominant, heterozygous dominant, and homozygous recessive genotypes, respectively. For each type of cross, determine the genotypic and phenotypic ratios, respectively. The first cross was already done for you.

Cross	Genotypic Ratio	Phenotypic Ratio
1. *DD x DD*	100% *DD*	100% dominant
2. *DD x Dd*		
3. *DD x dd*		
4. *Dd x Dd*		
5. *Dd x dd*		
6. *dd x dd*		

This table summarizes the genotypic and phenotypic ratios of typical Mendelian traits. Knowing the Mendelian genotypic and phenotypic ratios can make solving genetic problems easier.

Cross with Two Factors (Dihybrid Cross)

Mendel also studied the inheritance of two pairs of factors in an individual. A cross between individuals that involve two heterozygous pairs of genes is called a **dihybrid cross**.

Mendel crossed a plant with genotype *RRYY* (round, yellow seeds) and a plant with genotype *rryy* (wrinkled, green seeds). The F_1 peas exhibited the dominant traits for the heterozygous genotype *RrYy*. Assuming Mendel's Law of Segregation, each pair will segregate during the formation of gametes. Each gamete will therefore receive one allele from each pair. If the pairs of alleles are found on different chromosomes, then each dihybrid will produce four different types of gametes with ¼ probability each (Figure 12).

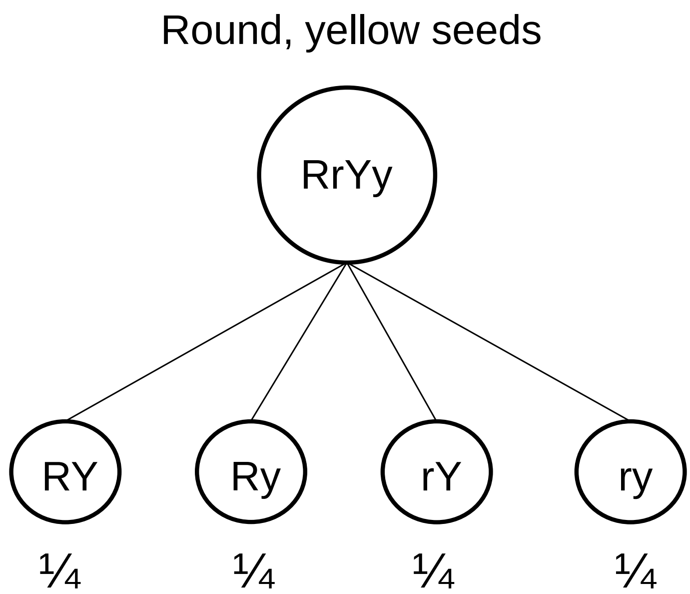


Figure 12. Gametes produced by a dihybrid genotype.

Self-fertilization of F_1 peas produced four phenotypes. The phenotypes with a ratio 9:3:3:1 are as follows:

9	(round, yellow seed)
3	(round, green seed)
3	(wrinkled, yellow seed)
1	(wrinkled, green seed)

Can you show, using a Punnett square, how this phenotype is obtained?

Activity 5
Filling up the Punnett square for a dihybrid cross

Objective:

At the end of this activity, you should be able to use a Punett square when solving for dihybrid crosses.

Procedure:

Given the cross *RrYy* x *RrYy*, copy and fill up the Punnett square below. Base your answers to the given questions on the completed diagram.

♀ ♂				

Q1. What are the male gametes? female gametes?

Q2. What proportion of the offspring will have the following phenotype: *RY, Ry, rY,* and *ry*?

Q3. How many kinds of genotypes will the offspring have?

Q4. What is the probability that an individual will have a genotype of *RRyy*? *RrYy*? *Rryy*? *RRYY*?

Law of Independent Assortment

From the results obtained from his hybrid crosses, Mendel formulated his last hypothesis: *The distribution or assortment of one pair of factors is independent of the distribution of the other pair*.

The law of independent assortment explains why traits are inherited independent of each other. The law applies to factors (or genes) that are found on separate chromosomes. Since they are found on separate chromosomes, the segregation of one pair of factors is not affected by the segregation of the other pair. Therefore, their distribution in the resulting gametes will be at random (Figure 13).

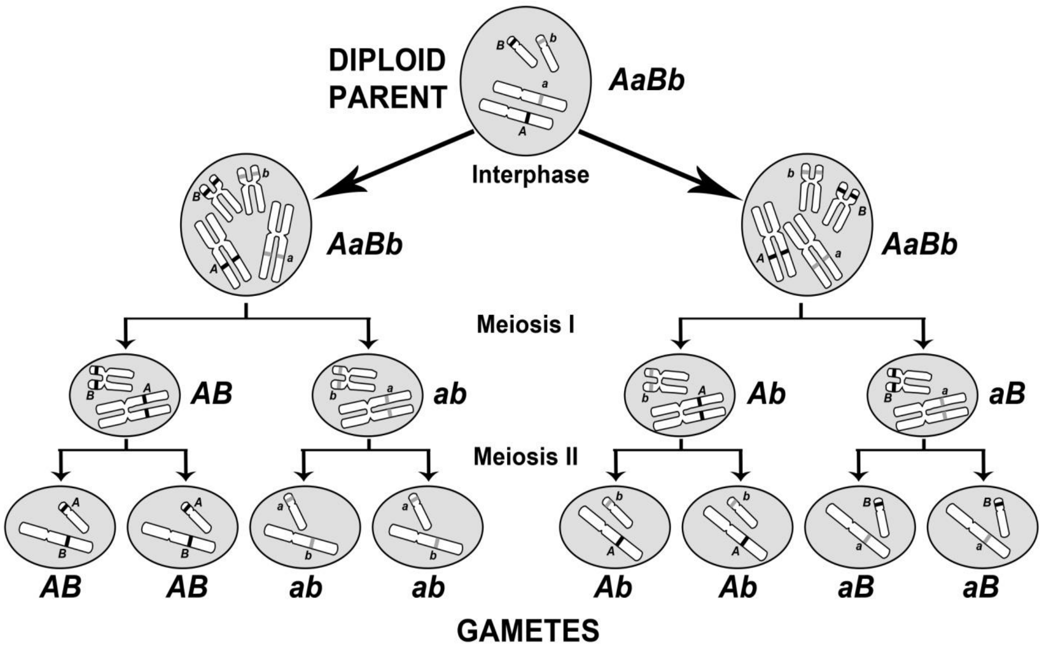


Figure 13. Chromosomal basis of Mendel's Law of Independent Assortment.

The Birth of the Science of Genetics

Mendel published his experimental results and analysis in 1866. However, biologists of that time paid little attention to them. Nobody tried to repeat Mendel's experiments or to apply the techniques he used to study the different traits in other organisms. For many years, Mendel's results remained unnoticed. However, these results were rediscovered independently in 1900 by three scientists, namely: Karl Correns, Hugo de Vries, and Erich Tschermark von Seysenegg. Only then did the scientific world come to know and benefit from Mendel's findings.

This rediscovery marked the beginning of the analytical study of heredity. It also gave birth to genetics as a new science, founded on Mendel's findings. Genetics also includes the study of genes and chromosomes and their properties and behavior in cells, individuals, and the population.

Non-Mendelian Patterns of Inheritance

Are all traits controlled by a dominant or a recessive gene? What about traits that have more than two phenotypes? Do they follow Mendelian patterns of inheritance?

1. Incomplete Dominance

When a pure red-flowered four o'clock plant is crossed with a pure white-flowered four o'clock plant, the offspring will produce neither red nor white flowers. Instead, all flowers will be pink. In other words, the offspring will have a phenotype intermediate between the phenotype of both parents. Such a phenomenon is called **incomplete dominance**. This means neither of the two alleles is completely dominant, and the heterozygous will be a new phenotype. Therefore, the genotypic ratio also becomes the phenotypic ratio.

Activity 6
Phenotypes and genotypes in incomplete dominance

Objective:

This activity will reinforce the genotypic and phenotypic ratios in a typical incompletely dominant trait.

Procedure:

In four o'clock plants, R_1 is the allele for red color and R_2 is for white color. Two pink flowered plants were crossed.

Q1. How many types of gametes will each parent produce?

Q2. What are the phenotypes of the offspring?

Another cross was made involving a red flowered plant and a pink flowered plant.

Q3. What would be the phentopytic and genotypic ratios of the offspring of this cross?

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2. Codominance

Another pattern of inheritance is **codominance**. This results when one allele is not dominant over the other. The resulting heterozygotes exhibit the traits of both parents. One example of codominance is the MN blood typing in humans.

On the surface of our red blood cells are proteins bound to sugar molecules, forming complexes called antigens. One group of antigens are controlled by a pair of alleles, L^M and L^N. The pairing of these alleles will determine the blood type of an individual, and there are three: M, MN and N. Table 5 summarizes the genotypes and phenotypes of the MN blood typing in humans.

Table 5. Human MN blood types and their genotypes.

Blood Types	Genotypes
M	$L^M L^M$
MN	$L^M L^N$
N	$L^N L^N$

Note that in the heterozygote condition, both L^M and L^N alleles are expressed in that the red blood cells will have the M and N antigens. Just like in incomplete dominance, the genotypic ratio in codominance also becomes the phenotypic ratio.

3. Multiple Alleles

Sometimes, even if only two alleles control a trait, there may actually be more than two types of alleles available. This will also lead to more than two phenotypes expressed.

Another blood group system in humans, the ABO system, is an example of a character governed by multiple alleles. Three alleles are responsible for this blood system: I^A, I^B, and i. The ABO blood type is determined by the presence or absence of two antigens, A and B. Allele i does not code for an antigen. There are four possible blood types as shown in Table 6.

Table 6. Human ABO blood types and their phenotypes.

Blood Types	Genotypes
A	$I^A\ I^A$, $I^A\ i$
B	$I^B\ I^B$, $I^B\ i$
AB	$I^A\ I^B$
O	$i\ i$

The I^A and I^B alleles are dominant over the i allele, which is always recessive. However, when the I^A and I^B alleles are inherited together, both alleles are expressed equally. This also makes I^A and I^B codominants of each other.

Activity 7
Inferring genotypes of ABO blood types based on the parental blood types

Objective:

By the end of this activity, you should be able to infer the unknown phenotypes of individuals on the basis of the known phenotypes of their family members.

Procedure:

Given the blood types of the mother and the child, identify the possible blood types of the father.

Mother's Blood Type	Father's Blood Type	Child's Blood Type
A		A
B		AB
AB		B
O		O

Sex Chromosomes and Sex Determination

Observation of the human body cells shows 23 pairs of chromosomes for both male and females. 22 pairs are somatic chromosomes. The 23rd pair consists of sex chromosomes.

Human males and some other male organisms, such as other mammals and fruit flies, have non-identical sex chromosomes (*XY*). Females have identical (*XX*) sex chromosomes.

Let us study gamete formation based on the sex chromosomes. You will observe in Figure 14 that all egg cells receive an *X* chromosome from a germ cell, while half of the sperm cells receive *X* chromosomes and the other half receive *Y* chromosomes.

If an egg is fertilized by a sperm with a *Y* chromosome, as shown in Figure 11, the offspring is male. When an egg is fertilized by a sperm carrying an *X* chromosome, the offspring is female. Note that there is a 50 percent chance of having a male or female offspring. The greater the number of offspring, the greater is the chance of getting the expected 1:1 ratio of male and female.

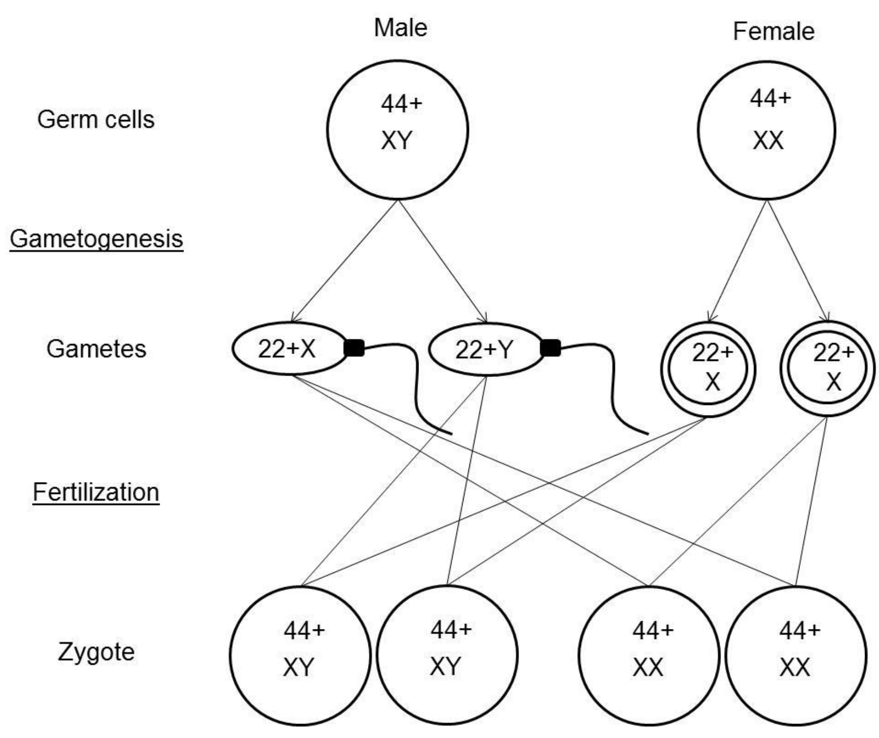

Figure 14. Types of gametes produced based on the sex chromosomes in humans and the ratio of the zygotes generated after fertilization.

4. Sex-Linked Genes

Genes located on the *X* chromosomes are called *X*-linked genes. Genes on the *Y* chromosomes are called *Y*-linked genes.

An example of an *X*-linked trait in humans is hemophilia. A person suffering from hemophilia could die from loss of blood even from a small wound because the blood either clots very slowly or does not clot at all. Another example of *X*-linked trait is color blindness.

To illustrate the inheritance of an *X*-linked trait, we will use color blindness in our discussion. Study Table 7. The *X* chromosome with the gene for color blindness is represented as X^C, while the one without is represented as *X.*

Table 7. Genotypes and phenotypes of color blindness in humans.

Genotype	Phenotype
1. XX	normal female
2. XX^C	normal female, carrier of the gene
3. X^CX^C	color blind female
4. XY	normal male
5. X^CY	color blind male

Notice that for a female to become color blind, she must be homozygous (X^CX^C) for the color blind genes. The trait is therefore recessive in females. If a female only has one *X* chromosome with the allele for color blindness, she becomes normal but can pass on the trait to her offspring. She is therefore a carrier for the trait.

Since males have only one *X* chromosome, the gene for color blindness when present in the male will always be expressed because it does not have an allele to hide or prevent its expression. Thus, the male will be color blind. This is the reason why color blindness is more common in males than in females.

An example of a *Y*-linked trait is **hypertrichosis pinnae auris**, a genetic disorder in humans that causes hairy ears. Since the trait is found in the *Y* chromosome, then only males can have the trait. A father who has the condition will pass it on to all his sons, and they, in turn, will pass it on to their own sons.

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