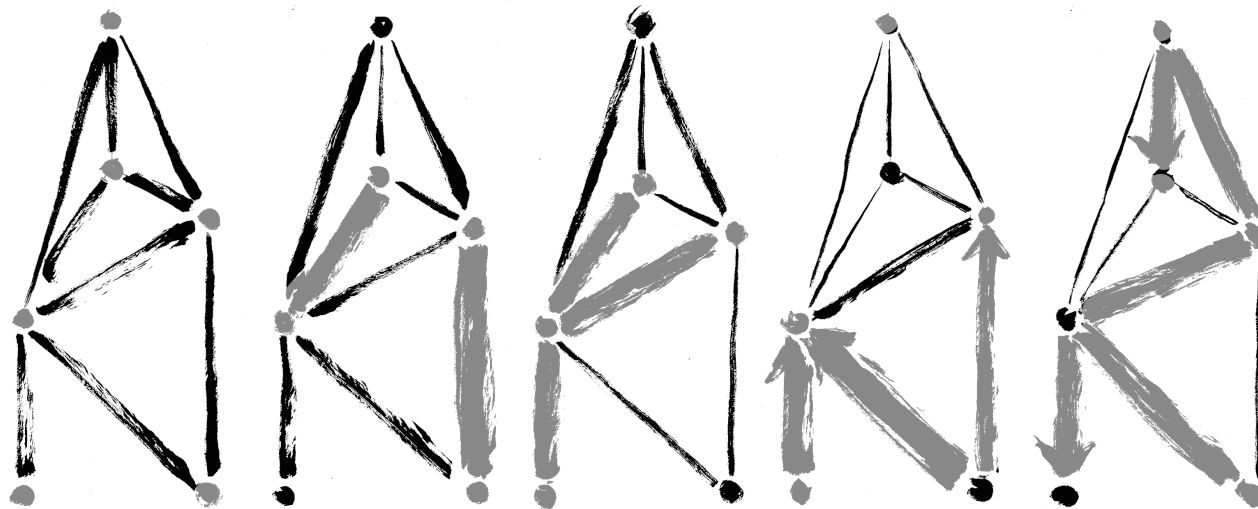


*The Commission on Higher Education
in collaboration with the Philippine Normal University*



Teaching Guide for Senior High School **INITIAL RELEASE JUNE 13, 2016**

EARTH AND LIFE SCIENCE

CORE SUBJECT

This Teaching Guide was collaboratively developed and reviewed by educators from public and private schools, colleges, and universities. We encourage teachers and other education stakeholders to email their feedback, comments, and recommendations to the Commission on Higher Education, K to 12 Transition Program Management Unit - Senior High School Support Team at k12@ched.gov.ph. We value your feedback and recommendations.



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Introduction

As the Commission supports DepEd's implementation of Senior High School (SHS), it upholds the vision and mission of the K to 12 program, stated in Section 2 of Republic Act 10533, or the Enhanced Basic Education Act of 2013, that "every graduate of basic education be an empowered individual, through a program rooted on...the competence to engage in work and be productive, the ability to coexist in fruitful harmony with local and global communities, the capability to engage in creative and critical thinking, and the capacity and willingness to transform others and oneself."

To accomplish this, the Commission partnered with the Philippine Normal University (PNU), the National Center for Teacher Education, to develop Teaching Guides for Courses of SHS. Together with PNU, this Teaching Guide was studied and reviewed by education and pedagogy experts, and was enhanced with appropriate methodologies and strategies.

Furthermore, the Commission believes that teachers are the most important partners in attaining this goal. Incorporated in this Teaching Guide is a framework that will guide them in creating lessons and assessment tools, support them in facilitating activities and questions, and assist them towards deeper content areas and competencies. Thus, the introduction of the **SHS for SHS Framework**.

SHS for SHS Framework

The SHS for SHS Framework, which stands for "Saysay-Husay-Sarili for Senior High School," is at the core of this book. The lessons, which combine high-quality content with flexible elements to accommodate diversity of teachers and environments, promote these three fundamental concepts:

SAYSAY: MEANING

Why is this important?

Through this Teaching Guide, teachers will be able to facilitate an understanding of the value of the lessons, for each learner to fully engage in the content on both the cognitive and affective levels.

HUSAY: MASTERY

How will I deeply understand this?

Given that developing mastery goes beyond memorization, teachers should also aim for deep understanding of the subject matter where they lead learners to analyze and synthesize knowledge.

SARILI: OWNERSHIP

What can I do with this?

When teachers empower learners to take ownership of their learning, they develop independence and self-direction, learning about both the subject matter and themselves.

About this Teaching Guide

Implementing this course at the senior high school level is subject to numerous challenges with mastery of content among educators tapped to facilitate learning and a lack of resources to deliver the necessary content and develop skills and attitudes in the learners, being foremost among these.

In support of the SHS for SHS framework developed by CHED, these teaching guides were crafted and refined by biologists and biology educators in partnership with educators from focus groups all over the Philippines to provide opportunities to develop the following:

- 1. Saysay** through meaningful, updated, and context-specific content that highlights important points and common misconceptions so that learners can connect to their real-world experiences and future careers;
- 2. Husay** through diverse learning experiences that can be implemented in a resource-poor classroom or makeshift laboratory that tap cognitive, affective, and psychomotor domains are accompanied by field-tested teaching tips that aid in facilitating discovery and development of higher-order thinking skills; and
- 3. Sarili** through flexible and relevant content and performance standards allow learners the freedom to innovate, make their own decisions, and initiate activities to fully develop their academic and personal potential.

These ready-to-use guides are helpful to educators new to either the content or biologists new to the experience of teaching Senior High School due to their enriched content presented as lesson plans or guides. Veteran educators may also add ideas from these guides to their repertoire. The Biology Team hopes that this resource may aid in easing the transition of the different stakeholders into the new curriculum as we move towards the constant improvement of Philippine education.

Parts of the Teaching Guide

This Teaching Guide is mapped and aligned to the DepEd SHS Curriculum, designed to be highly usable for teachers. It contains classroom activities and pedagogical notes, and is integrated with innovative pedagogies. All of these elements are presented in the following parts:

1. Introduction

- Highlight key concepts and identify the essential questions
- Show the big picture
- Connect and/or review prerequisite knowledge
- Clearly communicate learning competencies and objectives
- Motivate through applications and connections to real-life

2. Motivation

- Give local examples and applications
- Engage in a game or movement activity
- Provide a hands-on/laboratory activity
- Connect to a real-life problem

3. Instruction/Delivery

- Give a demonstration/lecture/simulation/hands-on activity
- Show step-by-step solutions to sample problems
- Give applications of the theory
- Connect to a real-life problem if applicable

4. Practice

- Discuss worked-out examples
- Provide easy-medium-hard questions
- Give time for hands-on unguided classroom work and discovery
- Use formative assessment to give feedback

5. Enrichment

- Provide additional examples and applications
- Introduce extensions or generalisations of concepts
- Engage in reflection questions
- Encourage analysis through higher order thinking prompts

6. Evaluation

- Supply a diverse question bank for written work and exercises
- Provide alternative formats for student work: written homework, journal, portfolio, group/individual projects, student-directed research project

On DepEd Functional Skills and CHED College Readiness Standards

As Higher Education Institutions (HEIs) welcome the graduates of the Senior High School program, it is of paramount importance to align Functional Skills set by DepEd with the College Readiness Standards stated by CHED.

The DepEd articulated a set of 21st century skills that should be embedded in the SHS curriculum across various subjects and tracks. These skills are desired outcomes that K to 12 graduates should possess in order to proceed to either higher education, employment, entrepreneurship, or middle-level skills development.

On the other hand, the Commission declared the College Readiness Standards that consist of the combination of knowledge, skills, and reflective thinking necessary to participate and succeed - without remediation - in entry-level undergraduate courses in college.

The alignment of both standards, shown below, is also presented in this Teaching Guide - prepares Senior High School graduates to the revised college curriculum which will initially be implemented by AY 2018-2019.

College Readiness Standards Foundational Skills	DepEd Functional Skills
Produce all forms of texts (written, oral, visual, digital) based on: 1. Solid grounding on Philippine experience and culture; 2. An understanding of the self, community, and nation; 3. Application of critical and creative thinking and doing processes; 4. Competency in formulating ideas/arguments logically, scientifically, and creatively; and 5. Clear appreciation of one's responsibility as a citizen of a multicultural Philippines and a diverse world;	Visual and information literacies, media literacy, critical thinking and problem solving skills, creativity, initiative and self-direction
Systematically apply knowledge, understanding, theory, and skills for the development of the self, local, and global communities using prior learning, inquiry, and experimentation	Global awareness, scientific and economic literacy, curiosity, critical thinking and problem solving skills, risk taking, flexibility and adaptability, initiative and self-direction
Work comfortably with relevant technologies and develop adaptations and innovations for significant use in local and global communities	Global awareness, media literacy, technological literacy, creativity, flexibility and adaptability, productivity and accountability
Communicate with local and global communities with proficiency, orally, in writing, and through new technologies of communication	Global awareness, multicultural literacy, collaboration and interpersonal skills, social and cross-cultural skills, leadership and responsibility
Interact meaningfully in a social setting and contribute to the fulfilment of individual and shared goals, respecting the fundamental humanity of all persons and the diversity of groups and communities	Media literacy, multicultural literacy, global awareness, collaboration and interpersonal skills, social and cross-cultural skills, leadership and responsibility, ethical, moral, and spiritual values

**K to 12 BASIC EDUCATION CURRICULUM
SENIOR HIGH SCHOOL – CORE SUBJECT**

Grade: 11/12

Core Subject Title: Earth and Life Science

Academic Year: 1

No. of Hours: 80 hours (20 Weeks)

Pre-requisite (if needed):

Core Subject Description: This learning area is designed to provide a general background for the understanding of Earth Science and Biology. It presents the history of the Earth through geologic time. It discusses the Earth's structure, composition, and processes. Issues, concerns, and problems pertaining to natural hazards are also included. It also deals with the basic principles and processes in the study of biology. It covers life processes and interactions at the cellular, organism, population, and ecosystem levels.

GRADE 11 FIRST QUARTER				
CONTENT	CONTENT STANDARD	PERFORMANCE STANDARD	LEARNING COMPETENCIES	CODE
I. ORIGIN AND STRUCTURE OF THE EARTH A. Universe and Solar System B. Earth and Earth Systems	<i>The learners demonstrate an understanding of:</i> 1. the formation of the universe and the solar system 2. the subsystems (geosphere, hydrosphere, atmosphere, and biosphere) that make up the Earth 3. the Earth's internal structure	<i>The learners shall be able to:</i> 1. Conduct a survey to assess the possible geologic hazards that your community may experience. <i>(Note: Select this performance standard if your school is in an area near faultlines, volcanoes, and steep slopes.)</i> 2. Conduct a survey or design a study to assess the possible hydrometeorological hazards that your community may	<i>The learners:</i> 1. State the different hypotheses explaining the origin of the universe.	S11/12ES-Ia-e-1
			2. Describe the different hypotheses explaining the origin of the solar system.	S11/12ES-Ia-e-2
			3. Recognize the uniqueness of Earth, being the only planet in the solar system with properties necessary to support life.	S11/12ES-Ia-e-3
			4. Explain that the Earth consists of four subsystems, across whose boundaries matter and energy flow.	S11/12ES-Ia-e-4
			5. Explain the current advancements/information on the solar system	S11/12ES-Ia-e-5
			6. Show the contributions of personalities/people on the	S11/12ES-Ia-e-6

**K to 12 BASIC EDUCATION CURRICULUM
SENIOR HIGH SCHOOL – CORE SUBJECT**

CONTENT	CONTENT STANDARD	PERFORMANCE STANDARD	LEARNING COMPETENCIES	CODE	
		experience. (<i>Note: Select this performance standard if your school is in an area that is frequently hit by tropical cyclones and is usually flooded.</i>)	understanding of the earth systems		
			7. Identify the layers of the Earth (crust, mantle, core).	S11/12ES-Ia-e-7	
			8. Differentiate the layers of the Earth.	S11/12ES-Ia-e-8	
II. EARTH MATERIALS AND PROCESSES A. Minerals and Rocks	<i>The learners demonstrate an understanding of:</i> 1. the three main categories of rocks		<i>The learners:</i> 1. identify common rock-forming minerals using their physical and chemical properties 2. classify rocks into igneous, sedimentary, and metamorphic	S11/12ES-Ia-9	
	2. the origin and environment of formation of common minerals and rocks			S11/12ES-Ib-10	
	B. Exogenic Processes			3. describe how rocks undergo weathering	S11/12ES-Ib-11
				4. explain how the products of weathering are carried away by erosion and deposited elsewhere	S11/12ES-Ib-12
				5. make a report on how rocks and soil move downslope due to the direct action of gravity	S11/12ES-Ib-13
	C. Endogenic Processes			6. describe where the Earth’s internal heat comes from.	S11/12ES-Ib-14
				7. describe how magma is formed (magmatism)	S11/12ES-Ic-15
				8. describe what happens after the magma is formed (plutonism and volcanism)	S11/12ES-Ic-16
				9. describe the changes in mineral components and texture of rocks due to changes in pressure and temperature (metamorphism)	S11/12ES-Ic-17
				5. the folding and faulting of rocks	

**K to 12 BASIC EDUCATION CURRICULUM
SENIOR HIGH SCHOOL – CORE SUBJECT**

CONTENT	CONTENT STANDARD	PERFORMANCE STANDARD	LEARNING COMPETENCIES	CODE
			10. compare and contrast the formation of the different types of igneous rocks	S11/12ES-Ic-18
			11. describe how rocks behave under different types of stress such as compression, pulling apart, and shearing	S11/12ES-Ic-19
D. Deformation of the Crust	6. plate tectonics		12. explain how the continents drift	S11/12ES-Id-20
			13. cite evidence that support continental drift	S11/12ES-Id-21
			14. explain how the movement of plates leads to the formation of folds and faults	S11/12ES-Id-22
			15. explain how the seafloor spreads	S11/12ES-Id-23
			16. describe the structure and evolution of ocean basins	S11/12ES-Id-24
			17. describe how layers of rocks (stratified rocks) are formed	S11/12ES-Ie-25
E. History of the Earth	7. how the planet Earth evolved in the last 4.6 billion years (including the age of the Earth, major geologic time subdivisions, and marker fossils).		18. describe the different methods (relative and absolute dating) to determine the age of stratified rocks	S11/12ES-Ie-26
			19. explain how relative and absolute dating were used to determine the subdivisions of geologic time	S11/12ES-Ie-27
			20. describe how marker fossils (also known as guide fossils) are used to define and identify subdivisions of the geologic time scale	S11/12ES-Ie-28

**K to 12 BASIC EDUCATION CURRICULUM
SENIOR HIGH SCHOOL – CORE SUBJECT**

CONTENT	CONTENT STANDARD	PERFORMANCE STANDARD	LEARNING COMPETENCIES	CODE
			21. describe how the Earth's history can be interpreted from the geologic time scale	S11/12ES-Ie-29
III. NATURAL HAZARDS, MITIGATION, AND ADAPTATION	<i>The learners demonstrate an understanding of:</i>		<i>The learners:</i>	
A. Geologic Processes and Hazards	1. the different hazards caused by geological processes (earthquakes, volcanic eruptions, and landslides)		1. describe the various hazards that may happen in the event of earthquakes, volcanic eruptions, and landslides	S11/12ES-If-30
B. Hydrometeorological Phenomena and Hazards	2. the different hazards caused by hydrometeorological phenomena (tropical cyclones, monsoons, floods, and tornadoes or <i>ipo-ipo</i>)		3. using hazard maps, identify areas prone to hazards brought about by earthquakes, volcanic eruptions, and landslides	S11/12ES-If-31
			4. give practical ways of coping with geological hazards caused by earthquakes, volcanic eruptions, and landslides	S11/12ES-If-32
			5. identify human activities that speed up or trigger landslides	S11/12ES-If-33
			6. suggest ways to help lessen the occurrence of landslides in your community	S11/12ES-Ig-34
C. Marine and Coastal Processes and their Effects	3. the different hazards caused by coastal processes (waves, tides, sea-level changes, crustal movement, and storm surges)		7. describe the various hazards that may happen in the wake of tropical cyclones, monsoons, floods, or ipo-ipo	S11/12ES-Ig-35
			8. using hazard maps, identify areas prone to hazards brought about by tropical cyclones, monsoons, floods, or ipo-ipo	S11/12ES-Ig-36

**K to 12 BASIC EDUCATION CURRICULUM
SENIOR HIGH SCHOOL – CORE SUBJECT**

CONTENT	CONTENT STANDARD	PERFORMANCE STANDARD	LEARNING COMPETENCIES	CODE
			9. give practical ways of coping with hydrometeorological hazards caused by tropical cyclones, monsoons, floods, or ipo-ipo	S11/12ES-Ih-37
			10. describe how coastal processes result in coastal erosion, submersion, and saltwater intrusion	S11/12ES-Ih-38
			11. identify areas in your community prone to coastal erosion, submersion, and saltwater intrusion	S11/12ES-Ii-39
			12. give practical ways of coping with coastal erosion, submersion, and saltwater intrusion	S11/12ES-Ii-40
			13. cite ways to prevent or mitigate the impact of land development, waste disposal, and construction of structures on control coastal processes	S11/12ES-Ii-41

**K to 12 BASIC EDUCATION CURRICULUM
SENIOR HIGH SCHOOL – CORE SUBJECT**

CONTENT	CONTENT STANDARD	PERFORMANCE STANDARD	LEARNING COMPETENCIES	CODE
I. INTRODUCTION TO LIFE SCIENCE	<i>The learners demonstrate an understanding of:</i> - the historical development of the concept of life - the origin of the first life forms - unifying themes in the study of life	<i>The learners shall be able to:</i> value life by taking good care of all beings, humans, plants, and animals	<i>The learners:</i> explain the evolving concept of life based on emerging pieces of evidence	S11/12LT-IIa-1
			describe classic experiments that model conditions which may have enabled the first forms to evolve	S11/12LT-IIa-2
			describe how unifying themes (e.g., structure and function, evolution, and ecosystems) in the study of life show the connections among living things and how they interact with each other and with their environment	S11/12LT-IIa-3
II. BIOENERGETICS	<i>The learners demonstrate an understanding of:</i> - the cell as the basic unit of life - how photosynthetic organisms capture light energy to form sugar molecules - how organisms obtain and utilize energy	<i>The learners shall be able to:</i> make a poster that shows the complementary relationship of photosynthesis and cellular respiration	<i>The learners:</i> explain how cells carry out functions required for life	S11/12LT-IIbd-4
			explain how photosynthetic organisms use light energy to combine carbon dioxide and water to form energy-rich compounds	S11/12LT-IIbd-5
			trace the energy flow from the environment to the cells.	S11/12LT-IIbd-6
			describe how organisms obtain and utilize energy	S11/12LT-IIbd-7
			recognize that organisms require energy to carry out functions required for life	S11/12LT-IIbd-8

**K to 12 BASIC EDUCATION CURRICULUM
SENIOR HIGH SCHOOL – CORE SUBJECT**

CONTENT	CONTENT STANDARD	PERFORMANCE STANDARD	LEARNING COMPETENCIES	CODE
III. PERPETUATION OF LIFE	<i>The learners demonstrate an understanding of:</i>	<i>The learners shall be able to:</i> conduct a survey of products containing substances that can trigger genetic disorders such as phenylketonuria	<i>The learners:</i> 1. describe the different ways of how plants reproduce	S11/12LT-IIej-13
	1. plant and animal reproduction		2. illustrate the relationships among structures of flowers, fruits, and seeds	S11/12LT-IIej-14
			3. describe the different ways of how representative animals reproduce	S11/12LT-IIej-15
	2. how genes work		4. explain how the information in the DNA allows the transfer of genetic information and synthesis of proteins	S11/12LT-IIej-16
	3. how genetic engineering is used to produce novel products		5. describe the process of genetic engineering	S11/12LT-IIej-17
			6. conduct a survey of the current uses of genetically modified organisms	S11/12LT-IIej-18
			7. evaluate the benefits and risks of using GMOs	S11/12LT-IIej-19
IV. HOW ANIMALS SURVIVE	<i>The learners demonstrate an understanding of:</i> 1. nutrition: getting food to cells 2. gas exchange with the environment	<i>The learners shall be able to:</i> make a presentation of some diseases that are associated with the various organ systems	<i>The learners:</i> 8. explain the different metabolic processes involved in the various organ systems	S11/12LT-IIIaj-20

**K to 12 BASIC EDUCATION CURRICULUM
SENIOR HIGH SCHOOL – CORE SUBJECT**

CONTENT	CONTENT STANDARD	PERFORMANCE STANDARD	LEARNING COMPETENCIES	CODE
	3. circulation: the internal transport system 4. the need for homeostasis 5. salt and water balance and waste removal 6. the immune system: defense from disease 7. how hormones govern body activities 8. the nervous system 9. the body in motion		9. describe the general and unique characteristics of the different organ systems in representative animals	S11/12LT-IIIaj-21
			10. analyze and appreciate the functional relationships of the different organ systems in ensuring animal survival	S11/12LT-IIIaj-22
V. HOW PLANTS SURVIVE	<i>The learners demonstrate an understanding of:</i> 1. plant form and function 2. plant growth and development	<i>The learners shall be able to:</i> design a setup on propagating plants using other methods such as hydroponics and aeroponics	<i>The learners:</i> 11. describe the structure and function of the different plant organs	S11/12LT-IVae-23
			12. explain the different metabolic processes involved in the plant organ systems	S11/12LT-IVae-24

**K to 12 BASIC EDUCATION CURRICULUM
SENIOR HIGH SCHOOL – CORE SUBJECT**

CONTENT	CONTENT STANDARD	PERFORMANCE STANDARD	LEARNING COMPETENCIES	CODE
VI. THE PROCESS OF EVOLUTION	<i>The learners demonstrate an understanding of:</i> - the evidence for evolution - the origin and extinction of species	<i>The learners shall be able to:</i> Design a poster tracing the evolutionary changes in a crop plant (e.g., rice or corn) that occurred through domestication	<i>The learners:</i> 13. describe evidence of evolution such as homology, DNA/protein sequences, plate tectonics, fossil record, embryology, and artificial selection/agriculture	S11/12LT-IVfg-25
			13. explain how populations of organisms have changed and continue to change over time showing patterns of descent with modification from common ancestors to produce the organismal diversity observed today	S11/12LT-IVfg-26
			14. describe how the present system of classification of organisms is based on evolutionary relationships	S11/12LT-IVfg-27
VII. INTERACTION AND INTERDEPENDENCE	<i>The learners demonstrate an understanding of:</i> - the principles of the ecosystem - biotic potential and environmental resistance - terrestrial and aquatic ecosystems	<i>The learners shall be able to:</i> prepare an action plan containing mitigation measures to address current environmental concerns and challenges in the community	<i>The learners:</i> 15. describe the principles of the ecosystem	S11/12LT-IVhj-28
			16. categorize the different biotic potential and environmental resistance (e.g., diseases, availability of food, and predators) that affect population explosion	S11/12LT-IVhj-29

**K to 12 BASIC EDUCATION CURRICULUM
SENIOR HIGH SCHOOL – CORE SUBJECT**

CONTENT	CONTENT STANDARD	PERFORMANCE STANDARD	LEARNING COMPETENCIES	CODE
	4. how human activities affect the natural ecosystem		17. describe how the different terrestrial and aquatic ecosystems are interlinked with one another	S11/12LT-IVhj-30

GLOSSARY

Absolute Dating

The process of determining an approximate computed age in archaeology and geology

**K to 12 BASIC EDUCATION CURRICULUM
SENIOR HIGH SCHOOL – CORE SUBJECT**

GLOSSARY

Artificial Selection	The process in the breeding of animals and in the cultivation of plants by which the breeder chooses to perpetuate only those forms having certain desirable traits or characteristics
Bioenergetics	Energy transformations and energy exchanges within and between living things and their environments
Calvin Cycle	The term for the cycle of dark reactions in photosynthesis
Embryology	The study of organisms at their early stages of development
Endogenic	Refers to internal processes and phenomena that occur beneath the Earth's surface, or any other celestial body's
Genetic Engineering	The deliberate and controlled manipulation of genes in an organism, with the intent of making that organism better in some way
Genetically Modified Organism	An organism whose genetic material has been altered using genetic engineering techniques. Organisms that have been genetically modified include micro-organisms such as bacteria and yeast, insects, plants, fish, and mammals
Geologic Process	A natural process whereby geological features are modified
Homology	The study of likeness in structure between parts of different organisms (e.g., the wing of a bat and the human arm) due to evolutionary differentiation from a corresponding part in a common ancestor
Hydrometeorological Hazards	The process or phenomenon of atmospheric, hydrological, or oceanographic nature that may cause loss of life, injury or other health impacts, property damage, loss of livelihoods and services, social and economic disruption, or environmental damage
Metamorphism	The process of dramatic changes in body form in the life cycle of some animals
Physiology	The study of the functions of living things and their parts
Plate Tectonics	The branch of geology that studies the folding and faulting of the Earth's crust
Plutonism	The formation of intrusive igneous rocks by solidification of magma beneath the earth's surface
Relative Dating	A technique used to determine the age of fossils by comparing them with other fossils in different layers of rock

Code Book Legend

**K to 12 BASIC EDUCATION CURRICULUM
SENIOR HIGH SCHOOL – CORE SUBJECT**

Sample: S11/12ES-Ia-e-1

LEGEND		SAMPLE	
First Entry	Learning Area and Strand/ Subject or Specialization	Science	S11/12
	Grade Level	Grade 11/12	
Uppercase Letter/s	Domain/Content/ Component/ Topic	Earth Science	ES
			-
Roman Numeral <i>*Zero if no specific quarter</i>	Quarter	First Quarter	I
Lowercase Letter/s <i>*Put a hyphen (-) in between letters to indicate more than a specific week</i>	Week	Weeks one to five	a-e
			-
Arabic Number	Competency	State the different hypotheses explaining the origin of the universe	1

DOMAIN/ COMPONENT	CODE
Earth Science	ES
Life Science	LT

Lesson 1: Universe and the Solar System

Content Standard

The learners demonstrate an understanding of the formation of the universe.

Learning Competency

The learners shall be able to state the different hypotheses and theories explaining the origin of the universe **(S11/12ES-la-e-1)**.

Specific Learning Outcomes

At the end of this lesson, the learners will be able to:

1. describe the structure and composition of the Universe;
2. state the different hypothesis that preceded the Big Bang Theory of the Origin of the Universe.
3. explain the red-shift and how it used as proof of an expanding universe; and
4. explain the Big Bang Theory and evidences supporting the theory.

LESSON OUTLINE

Introduction	Presentation of Objectives and Terms	10
Motivation	How big is a billion?	10
Instruction	Lecture Proper and Discussion	30
Enrichment	Will the Universe continue to Expand?	
Evaluation	Report	10

Materials

Projector or Print-out of Figures

Resources

- (1) http://imagine.gsfc.nasa.gov/educators/lesson_plans.html
- (2) <http://imagine.gsfc.nasa.gov/educators/materials.html>
- (3) <http://www.astro.princeton.edu/~dns/teachersguide/website.pdf>
- (4) http://map.gsfc.nasa.gov/universe/WMAP_Universe.pdf (accessed 3 October 2015)
- (5) <https://en.wikipedia.org/wiki/Universe> (accessed 4 October 2015)
- (6) <https://www.youtube.com/watch?v=RPVvgJoddO4&list=PLrhG2NtyHAZuPW5HP3cyenGGTUqUhumeQ> (accessed 25 October 2015)
- (7) Steinhardt P and N Turok. Endless Universe, <http://www.physics.princeton.edu/~steinh/endlessuniverse/askauthors.html> (accessed 13 October 2015)

Additional Resources at the End of this Lesson

INTRODUCTION (10 MINS)

1. Introduce the following learning objectives and important terms
 - A. Describe the structure and composition of the Universe;
 - B. Explain the red-shift and how it used as proof of an expanding universe
 - C. State the different hypothesis that preceded the Big Bang Theory of the Origin of the Universe
 - D. Explain the Big Bang Theory

2. Introduce the list of important terms that learners will encounter.
 - A. **Baryonic matter** - "ordinary" matter consisting of protons, electrons, and neutrons that comprises atoms, planets, stars, galaxies, and other bodies
 - B. **Dark matter** - matter that has gravity but does not emit light.
 - C. **Dark Energy** - a source of anti-gravity; a force that counteracts gravity and causes the universe to expand.
 - D. **Protostar** - an early stage in the formation of a star resulting from the gravitational collapse of gases.
 - E. **Thermonuclear reaction** - a nuclear fusion reaction responsible for the energy produced by stars.
 - F. **Main Sequence Stars** - stars that fuse hydrogen atoms to form helium atoms in their cores; outward pressure resulting from nuclear fusion is balanced by gravitational forces
 - G. **Light years** - the distance light can travel in a year; a unit of length used to measure astronomical distance

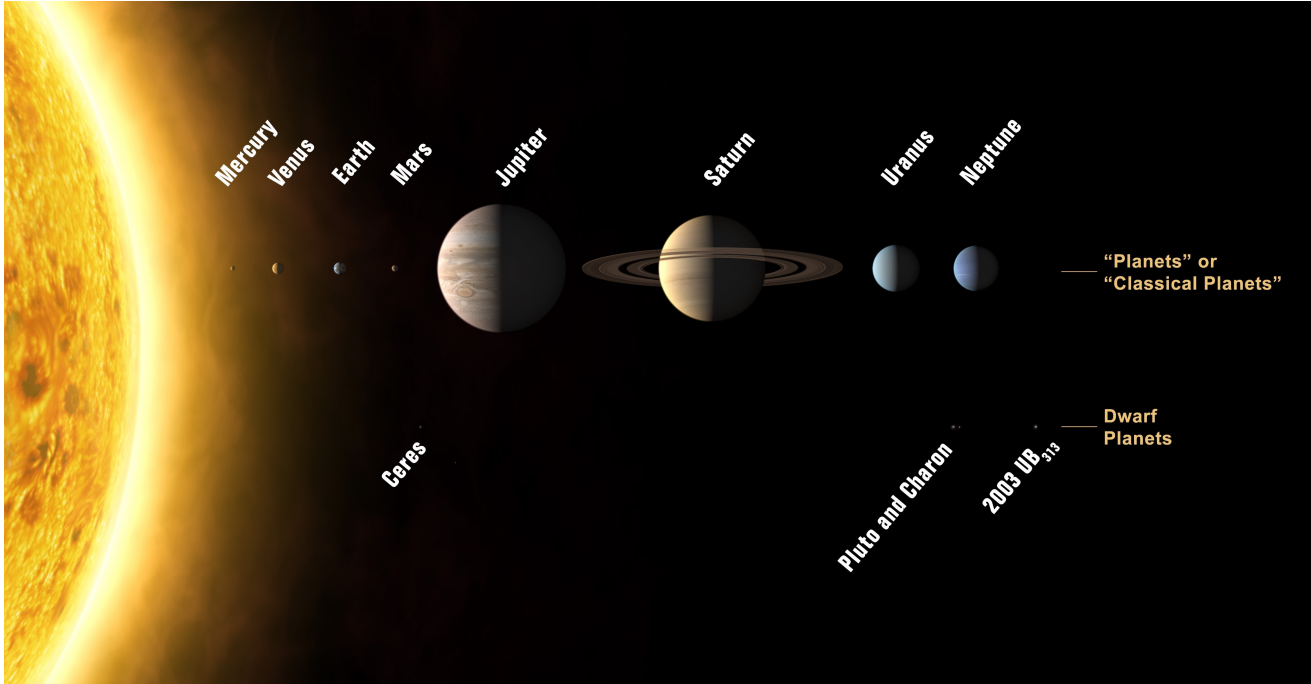
Teacher Tip:

Alternatively, these terms can be defined during the instruction/delivery.

MOTIVATION (10 MINS)

Connect the lesson to a real-life problem or question.

1. Tell the learners that the Universe is at least 13.8 billion of years old and the Earth/Solar System at least 4.5-4.6 billions of years old. But how large exactly is a billion? Ask the learners how long will it take them to spend 1 billion pesos if they spend 1 peso per second.
 - $1 \text{ billion} / (60 \text{ s/min} \times 60 \text{ min/hr} \times 24 \text{ hr/day} \times 365 \text{ days/year})$
 - ~32 years
 - How long is 13.8 billion years?
2. Show learners the series of photographs as follows:



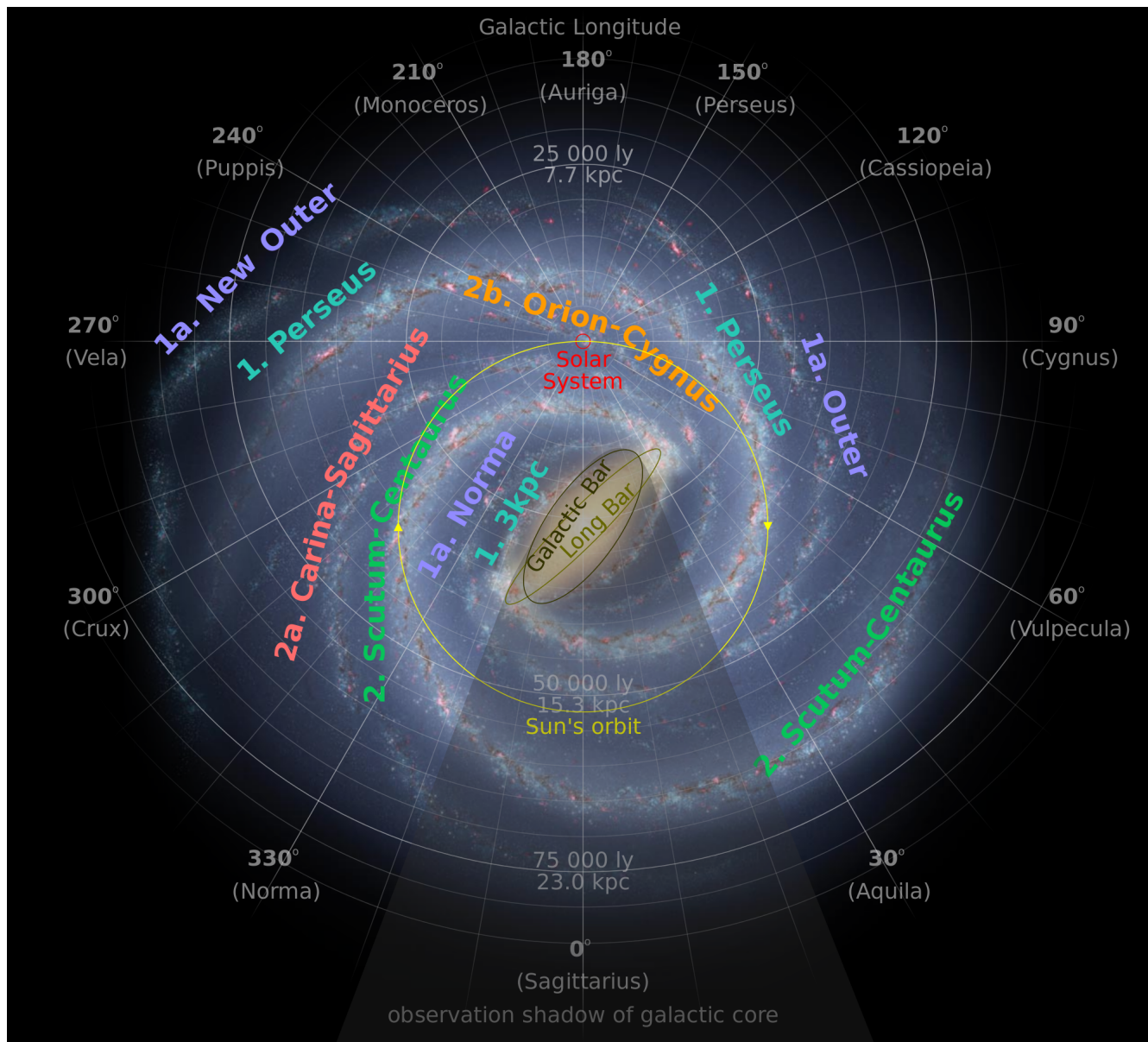
Source: The Solar System ([https://upload.wikimedia.org/wikipedia/commons/d/d9/Solar_System_\(annotated\).jpg](https://upload.wikimedia.org/wikipedia/commons/d/d9/Solar_System_(annotated).jpg))

Teacher Tip

- The purpose of the activity is to emphasize the immensity of time and by extension (relationship between space and time) the vastness of space (universe).
- Alternatively, you may also ask learners what they know about the universe.

Situate the Earth (and by extension themselves) with respect to the Universe

- The Earth as part of the solar system - inner terrestrial (as opposed to the outer gaseous planets) . Earth is also known as "the third rock from the Sun".
- The solar system as part of the Milky Way Galaxy. Note the Sun (solar system) is at the outer limb of the galaxy (not at the center!)



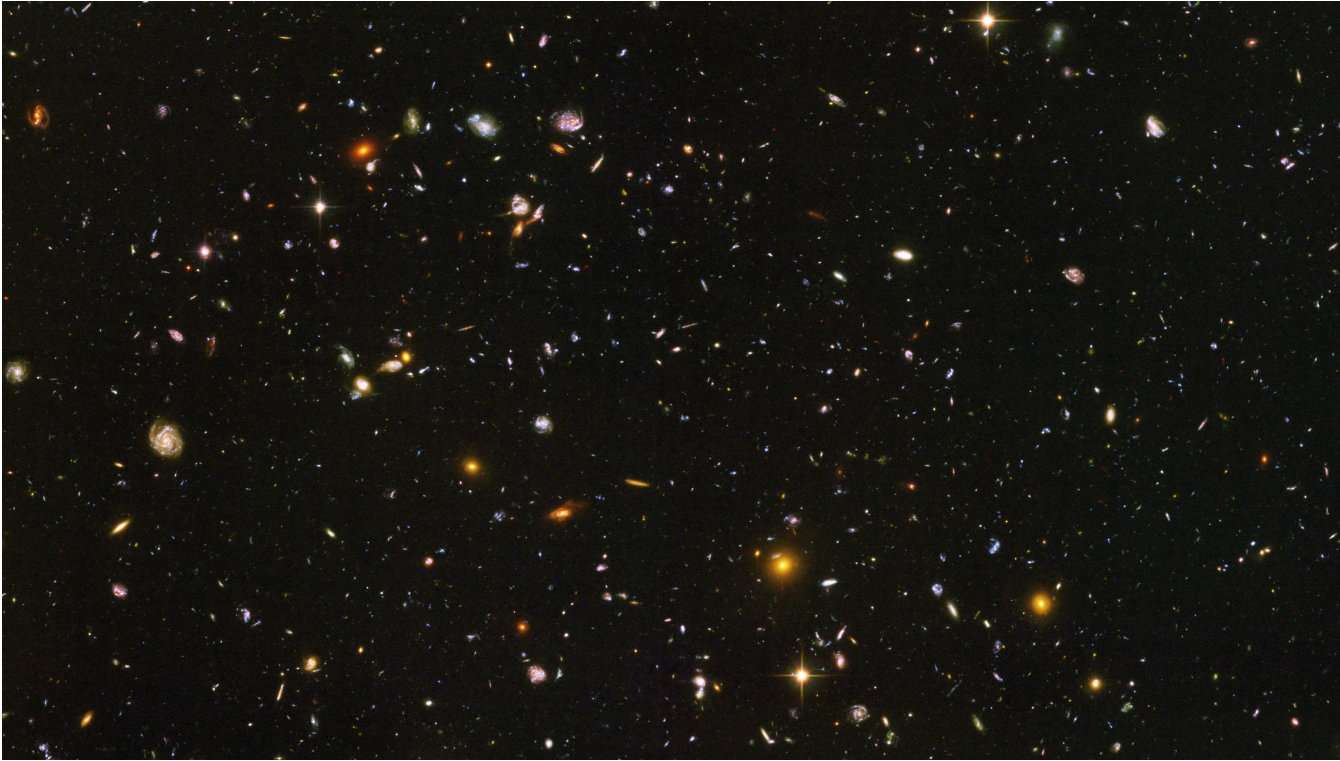
Teacher Tip:

- The Milky Way is but one of the billions of Galaxies in the Universe.
- We are definitely not at the center of the universe.
- Post the question to the learners and solicit their opinion:
- Is there a center?

You may check the following link to help in the discussion.

<http://math.ucr.edu/home/baez/physics/Relativity/GR/centre.html>

Source: The Milky Way (https://upload.wikimedia.org/wikipedia/commons/thumb/a/a7/Milky_Way_Arms_ssc2008-10.svg/2000px-Milky_Way_Arms_ssc2008-10.svg.png)



Source: The Hubble Deep Field (<https://www.google.com.ph/url?sa=i&rct=j&q=&esrc=s&source=images&cd=&ved=0ahUKEwjOuKaQlaTNAhXCqJQKHStrA5kQjBwIbA&url=http%3A%2F%2Fwallpapercave.com%2Fwp%2FTlqblsL.jpg&psig=AFQjCNFfHuF9reOYsnpNluRLoYAVcVeObA&ust=1465878504806484>)

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You may check the following link to help in the discussion.

<http://math.ucr.edu/home/baez/physics/Relativity/GR/centre.html>

INSTRUCTION (30 MINS)

Give a demonstration/lecture/simulation

Introduction:

Any explanation of the origin of the Universe should be consistent with all information about its **composition, structure, accelerating expansion, cosmic microwave background radiation** among others.

Structure, Composition, and Age

- The universe as we currently know it comprises all space and time, and all matter and energy in it.
- It is made of **4.6% baryonic matter** ("ordinary" matter consisting of protons, electrons, and neutrons: atoms, planets, stars, galaxies, nebulae, and other bodies), **24% cold dark matter** (matter that has gravity but does not emit light), and **71.4% dark energy** (a source of anti-gravity)
- Dark matter can explain what may be holding galaxies together for the reason that the low total mass is insufficient for gravity alone to do so while dark energy can explain the observed accelerating expansion of the universe.
- **Hydrogen, helium, and lithium** are the three most abundant elements.
- **Stars** - the building block of galaxies-are born out of clouds of gas and dust in galaxies. Instabilities within the clouds eventually results into gravitational collapse, rotation, heating up, and transformation into a **protostar**-the hot core of a future star as **thermonuclear reactions** set in.
- Stellar interiors are like furnaces where elements are synthesized or combined/fused together. Most stars such as the Sun belong to the so-called "**main sequence stars**." In the cores of such stars, hydrogen atoms are fused through **thermonuclear reactions** to make helium atoms. Massive main sequence stars burn up their hydrogen faster than smaller stars. Stars like our Sun burn up hydrogen in about 10 billion years.

Teacher Tip:

Hydrogen and Helium as the most abundant elements in the universe. Having the lowest mass, these are the first elements to be formed in the Big Bang Model of the Origin of the Universe.

- A star's energy comes from combining light elements into heavier elements by fusion, or "nuclear burning" (nucleosynthesis). In small stars like the sun, H burning is the fusion of 4 H nuclei (protons) into a He nucleus (2 protons + 2 neutrons).
- Forming He from H gives off lots of energy(i.e. a natural hydrogen bomb).
- Nucleosynthesis requires very high T. The minimum T for H fusion is 5×10^6 °C.

Birth, evolution, death, and rebirth of stars

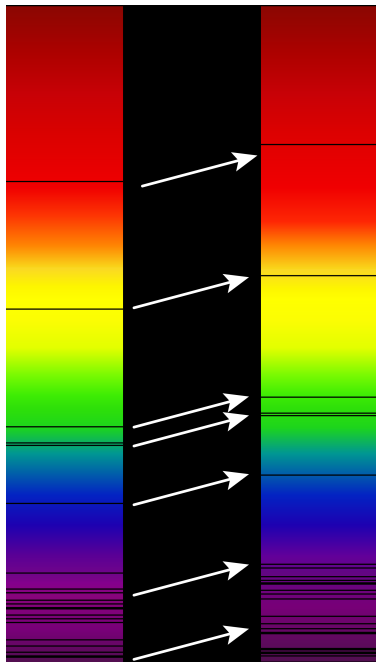
- The remaining dust and gas may end up as they are or as planets, asteroids, or other bodies in the accompanying planetary system.
- A **galaxy** is a cluster of billions of stars and clusters of galaxies form superclusters. In between the clusters is practically an empty space. This organization of matter in the universe suggests that it is indeed clumpy at a certain scale. But at a large scale, it appears homogeneous and isotropic.
- Based on recent data, the universe is **13.8 billion years old**. The diameter of the universe is possibly infinite but should be at least 91 billion light-years ($1 \text{ light-year} = 9.4607 \times 10^{12} \text{ km}$). Its density is $4.5 \times 10^{-31} \text{ g/cm}^3$.

Expanding Universe

- In 1929, Edwin Hubble announced his significant discovery of the **"redshift"** and its interpretation that galaxies are moving away from each other, hence as evidence for an expanding universe, just as predicted by Einstein's **Theory of General Relativity**.
- He observed that spectral lines of starlight made to pass through a prism are shifted toward the red part of the electromagnetic **spectrum**, i.e., toward the band of lower frequency; thus, the inference that the star or galaxy must be moving away from us.

Teacher Tip:

- This is similar to the **Doppler effect** for sound waves: to a stationary observer, the frequency or pitch of a receding source decreases as it moves away.



Red shift as evidence for an expanding universe. The positions of the absorptions lines for helium for light coming from the Sun are shifted towards the red end as compared with those for a distant star. This evidence for expansion contradicted the previously held view of a static and unchanging universe.

Source: The Red Shift (<https://www.google.com.ph/url?sa=i&rct=j&q=&esrc=s&source=images&cd=&ved=0ahUKEwjZwbe9mKTNAhWCUZQKHYNFAzMQjBwIBA&url=https%3A%2F%2Fupload.wikimedia.org%2Fwikipedia%2Fcommons%2Fthumb%2F6%2F6a%2FRedshift.svg%2F2000px-Redshift.svg.png&psig=AFQjCNEp2yshF0mgavwc8uQljiNouS9RyA&ust=1465879400062773>)

sa=i&rct=j&q=&esrc=s&source=images&cd=&ved=0ahUKEwjZwbe9mKTNAhWCUZQKHYNFAzMQjBwIBA&url=https%3A%2F%2Fupload.wikimedia.org%2Fwikipedia%2Fcommons%2Fthumb%2F6%2F6a%2FRedshift.svg%2F2000px-Redshift.svg.png&psig=AFQjCNEp2yshF0mgavwc8uQljiNouS9RyA&ust=1465879400062773)

Activity : Doppler Effect and Interactive

Source: <http://molebash.com/doppler/horn/horn1.ht>

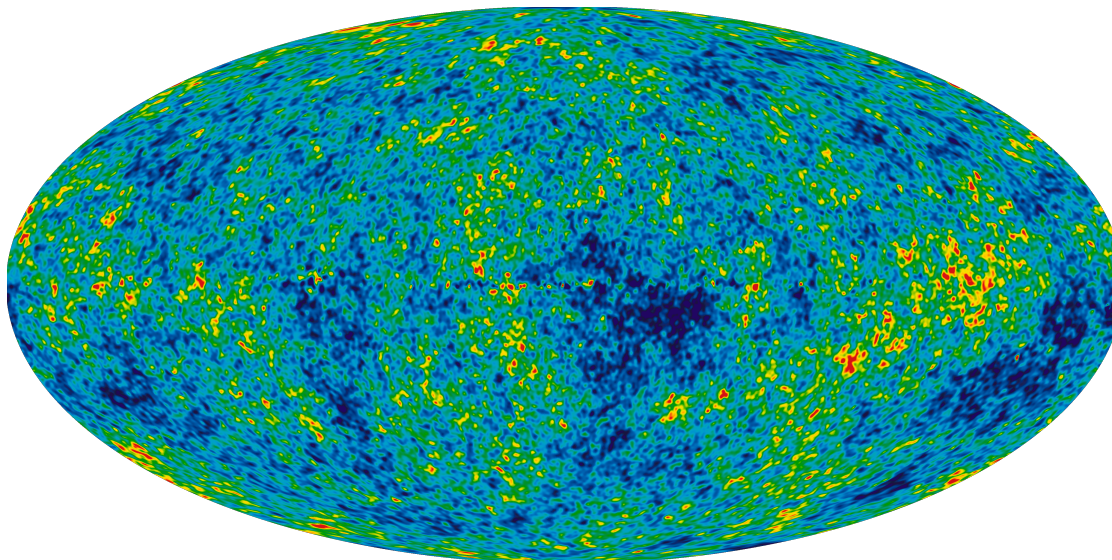
1. Ask the learners to watch two short video clips filmed inside a car. Try to determine where the horn is coming from. Is it coming from inside the car or outside the car? If outside the car, where?
 - Video 1 - horn is coming from the inside of the car. There is hardly any change in the volume and pitch of the horn.
 - Video 2 - horn is coming from outside of the car. Specifically, the horn is coming from another car travelling in an opposite direction. Notice how the pitch and volume of the car varies with distance from the other car. Pitch and volume increases as the other car approaches.

Teacher Tip:

- If there is internet access, you can play these two movie clips directly from the website; (<http://molebash.com/doppler/horn/horn1.htm>)
- Alternatively, the movie clips can be downloaded (also saved in the CD)

Cosmic Microwave Background

1. There is a pervasive cosmic microwave background (CMB) radiation in the universe. Its accidental discovery in 1964 by Arno Penzias and Robert Woodrow Wilson earned them the physics Nobel Prize in 1978.
2. It can be observed as a strikingly uniform faint glow in the microwave band coming from all directions-blackbody radiation with an average temperature of about 2.7 degrees above absolute zero.



Source: Cosmic microwave background radiation map showing small variations from WMAP - (Wilkinson Microwave Anisotropy Probe) (https://www.google.com.ph/url?sa=i&rct=j&q=&esrc=s&source=images&cd=&ved=0ahUKEwi-ia2AmqTNAhUHI5QKHcOjBjoQjBwIbA&url=https%3A%2F%2Fupload.wikimedia.org%2Fwikipedia%2Fcommons%2F3%2F3c%2FIlc_9yr_moll4096.png&bvm=bv.124272578,d.dGo&psig=AFQjCNFKLayV4rTg0JLSNVx2R6LonF7X_w&ust=1465879811382467)

Origin of the Universe

Non-scientific Thought

- Ancient Egyptians believed in many gods and myths which narrate that the world arose from an infinite sea at the first rising of the sun.
- The Kuba people of Central Africa tell the story of a creator god Mbombo (or Bumba) who, alone in a dark and water-covered Earth, felt an intense stomach pain and then vomited the stars, sun, and moon.
- In India, there is the narrative that gods sacrificed Purusha, the primal man whose head, feet, eyes, and mind became the sky, earth, sun, and moon respectively.
- The monotheistic religions of Judaism, Christianity, and Islam claim that a supreme being created the universe, including man and other living organisms.

Steady State Model

- The now discredited steady state model of the universe was proposed in 1948 by Bondi and Gould and by Hoyle.
- It maintains that new matter is created as the universe expands thereby maintaining its density.
- Its predictions led to tests and its eventual rejection with the discovery of the cosmic microwave background.

Big Bang Theory

- As the currently accepted theory of the origin and evolution of the universe, the Big Bang Theory postulates that 13.8 billion years ago, the universe expanded from a tiny, dense and hot mass to its present size and much cooler state.
- The theory rests on two ideas: General Relativity and the Cosmological Principle. In Einstein's General Theory of Relativity, gravity is thought of as a distortion of space-time and no longer described by a gravitational field in contrast to the Law of Gravity of Isaac Newton. General Relativity explains the peculiarities of the orbit of Mercury and the bending of light by the Sun and has passed rigorous tests. The Cosmological Principle assumes that the universe is homogeneous and isotropic when averaged over large scales. This is consistent with our current large-scale image of the universe. But keep in mind that it is clumpy at smaller scales.

Teacher Tip:

Unlike hypotheses in the sciences, religious beliefs cannot be subjected to tests using the scientific method. For this reason, they cannot be considered valid topic of scientific inquiry.

Teacher Tip:

The uniform nature (even in all direction) of the CMB precludes propagation from a point source (i.e. from ancient stars as explained by the steady state model).

Misconception:

The "bang" should not be taken as an explosion; it is better thought of a simultaneous appearance of space everywhere. The theory does not identify the cause of the "bang."

- The Big Bang Theory has withstood the tests for expansion: 1) the redshift 2) abundance of hydrogen, helium, and lithium, and 3) the uniformly pervasive cosmic microwave background radiation-the remnant heat from the bang.

Evolution of the Universe according to the Big Bang Theory

- From time zero (13.8 billion years ago) until 10^{-43} second later, all matter and energy in the universe existed as a hot, dense, tiny state. It then underwent extremely rapid, exponential inflation until 10^{-32} second later after which and until 10 seconds from time zero, conditions allowed the existence of only quarks, hadrons, and leptons.
- Then, Big Bang nucleosynthesis took place and produced protons, neutrons, atomic nuclei, and then hydrogen, helium, and lithium until 20 minutes after time zero when sufficient cooling did not allow further nucleosynthesis.
- From then on until 380,000 years, the cooling universe entered a matter-dominated period when photons decoupled from matter and light could travel freely as still observed today in the form of cosmic microwave background radiation.
- As the universe continued to cool down, matter collected into clouds giving rise to only stars after 380,000 years and eventually galaxies would form after 100 million years from time zero during which, through nucleosynthesis in stars, carbon and elements heavier than carbon were produced.
- From 9.8 billion years until the present, the universe became dark-energy dominated and underwent accelerating expansion. At about 9.8 billion years after the big bang, the solar system was formed.

Teacher Tip:

- It was previously thought that the gravity would eventually stop the expansion and end the universe with a "Big Crunch" and perhaps to generate another "bang" . This would occur if the density of the universe is greater than the critical density. But if it is lower, there would be not enough gravitational force to stop or reverse the expansion---the universe would expand forever leading to the "Big Chill" or "Big Freeze" since it cools during expansion. The recent observation of accelerating expansion suggests that the universe will expand exponentially forever.
- Submitted work may be evaluated using the following criteria:
- Logical discussion of scientific concepts used for the argument (e.g. effects of gravity, expansion), consistent discussions of pros and cons
- Logical build up of reasoning to support the choice.

ENRICHMENT (ASSIGNMENT)

1. Ask the learners to submit a brief report on the following topic/questions.

What is the fate of the universe? Will the universe continue to expand or will it eventually contract because of gravity?

EVALUATION

	EXCEEDS EXPECTATIONS	MEETS EXPECTATIONS	NEEDS IMPROVEMENT	NOT VISIBLE
Describes the structure and composition of the Universe.				
Explain the source of a star's energy.				
Explains the concept of the Red Shift and how it used as an evidence for an expanding universe.				
Applies understanding of the Doppler effect to differentiate between source of sound in two movie clips				
Describes the cosmic microwave background radiation and its significance				
States the different hypotheses that preceded the Big Bang Theory of the origin of the universe				
Explain the origin and evolution of the Universe according to the Big Bang Theory.				

Additional Resources:

- (1) <http://science.nasa.gov/astrophysics/focus-areas/how-do-stars-form-and-evolve/> (accessed: 12 october 2015)
- (2) <http://csep10.phys.utk.edu/astr161/lect/solarsys/solarsys.html> (accessed 12 October 2015)
- (3) https://en.wikipedia.org/wiki/History_of_Solar_System_formation_and_evolution_hypotheses#Classification_of_the_theories (accessed 13 October 2015)
- (4) "The Origin of the Universe, Earth, and Life." National Academy of Sciences. *Science and Creationism: A View from the National Academy of Sciences, Second Edition*. Washington, DC: The National Academies Press, 1999. <http://www.nap.edu/read/6024/chapter/3#8> (accessed 2 October 2015)
- (5) <http://science.nasa.gov/astrophysics/focus-areas/what-powered-the-big-bang/> (accessed 5 October 2015)
- (6) Activities for teaching of the Universe: <http://www.nuffieldfoundation.org/science-society/activities-universe> and <http://molebash.com/doppler/horn/horn1.htm>
- (7) Short article: <http://www.scholastic.com/teachers/article/?origin-universe>

Lesson 2: Universe and the Solar System

Content Standard

The learners demonstrate an understanding of the formation of the universe and the solar system.

Learning Competency

The learners shall be able to describe the different hypotheses explaining the origin of the solar system **(S11/12ES-la-e-2)** and explain the current advancements/information on the solar system **(S11/12ES-la-e-5)**

Specific Learning Outcomes

At the end of this lesson, the learners will be able to:

1. identify the large scale and small scale properties of the Solar System;
2. discuss the different hypotheses explaining the origin of the solar system; and
3. become familiar with the most recent advancements/information on the solar system.

LESSON OUTLINE

Introduction	Communicating Learning Objectives	10
Motivation	Understanding the Origin and Evolution of the Solar System	5
Instruction	Lecture Proper and Discussion	35
Enrichment and Evaluation	Assignment	10

Materials

Projector or Print-out of Figures

Resources

- (1) <http://csep10.phys.utk.edu/astr161/lect/solarsys/solarsys.html> (accessed 12 October 2015)
- (2) https://en.wikipedia.org/wiki/History_of_Solar_System_formation_and_evolution_hypotheses#Classification_of_the_theories (accessed 13 October 2015)
- (3) "The Origin of the Universe, Earth, and Life." National Academy of Sciences. *Science and Creationism: A View from the National Academy of Sciences, Second Edition*. Washington, DC: The National Academies Press, 1999. <http://www.nap.edu/read/6024/chapter/3#8> (accessed 2 October 2015)
- (4) <http://science.nasa.gov/astrophysics/focus-areas/what-powered-the-big-bang/> (accessed 5 October 2015)
- (5) <http://abyss.uoregon.edu/~js/ast121/lectures/lec24.html>
- (6) (accessed 27 March 2016)
- (7) http://discovery.nasa.gov/education/pdfs/Active%20Accretion_Discovery_508.pdf (accessed 27 March 2016)
- (8) <http://www.pbslearningmedia.org/resource/nsn11.sci.ess.eiu.solarorigins/origins-of-the-solar-system/> (accessed 27 March 2016)
- (9) http://dawn.jpl.nasa.gov/DawnClassrooms/pdfs/ActiveAccretion_Dawn.pdf (accessed 27 March 2016)

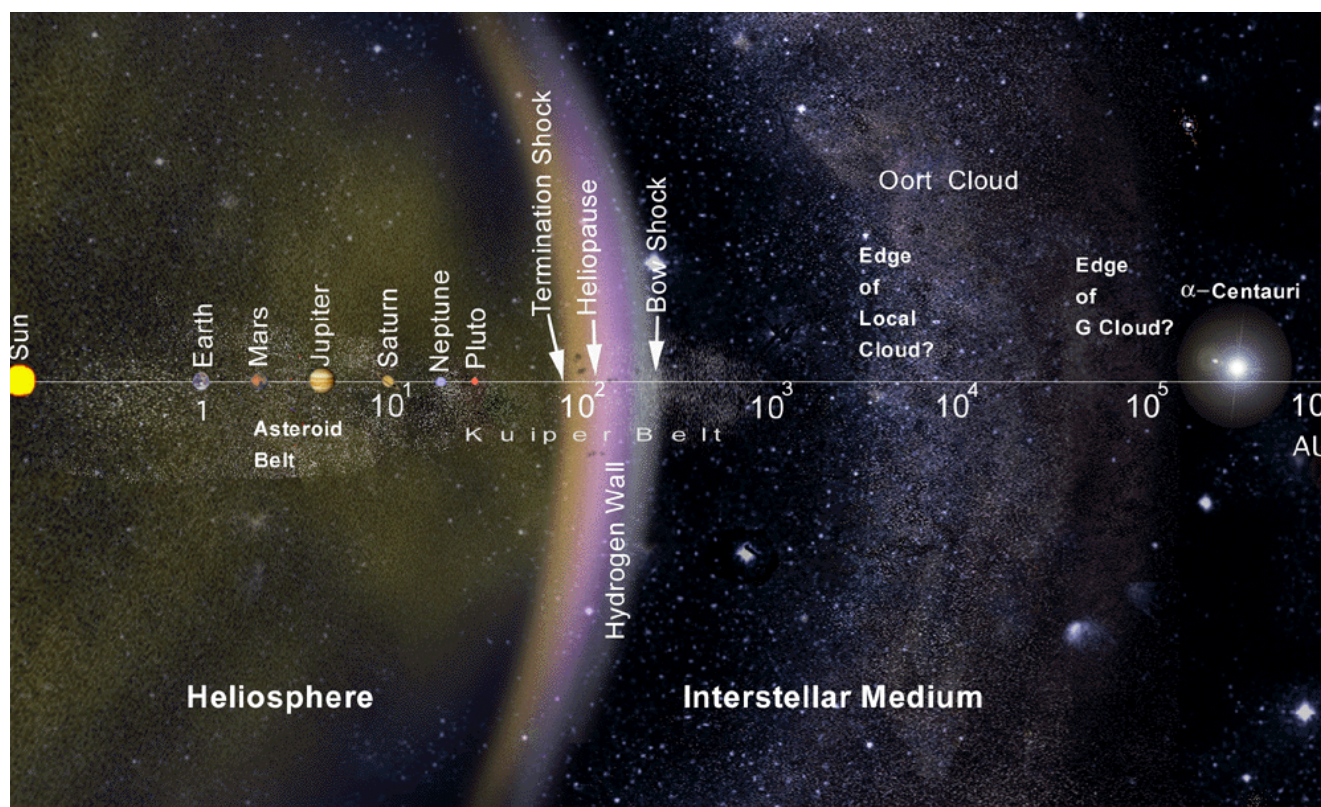
INTRODUCTION (10 MINS)

1. Introduce the following learning objectives:

At the end of this lesson, the learners will be able to:

- I. Identify the large scale and small scale properties of the Solar System;
- II. Discuss the different hypotheses explaining the origin of the solar system;
- III. Explain the significance of the most recent advancement/information on the Solar System.

2. Help learners recall what they have learned about the solar system by drawing a model on the board. Ask the learners for the correct sequence (from the inner planets to the outer planet).



Teacher Tips:

- The Solar System and its components have been discussed in Grade 6 and Grade 8 (astronomy)
- The solar system comprises the Sun, eight planets, dwarf planets such as Pluto, satellites, asteroids, comets, other minor bodies such as those in the Kuiper belt and interplanetary dust.
- The asteroid belt lies between Mars and Jupiter. Meteoroids are smaller asteroids. They are thought of as remnants of a “failed planet”—one that did not form due to disturbance from Jupiter’s gravity.
- The Kuiper belt lies beyond Neptune (30 to 50 AU, 1 AU = Sun-Earth distance = 150 million km) and comprise numerous rocky or icy bodies a few meters to hundreds of kilometers in size.
- The Oort cloud marks the outer boundary of the solar system and is composed mostly of icy objects

Source: Layout of the solar system comprising mainly the Sun, planets and their satellites, asteroids, and icy bodies such as dwarf planets and comets.

(<https://www.google.com.ph/url?sa=i&rct=j&q=&esrc=s&source=images&cd=&ved=0ahUKEwjue7soaTNAhUDGJQKHxjHAQ4QjBwIBA&url=https%3A%2F%2Fupload.wikimedia.org%2Fwikipedia%2Fcommons%2F9%2F9f%2FSolmap.png&bvm=bv.124272578,d.dGo&psig=AFQjCNGwA4eXmalQjoCkVRqF4n4bDTC6sw&ust=1465881919469816>)

MOTIVATION (5 MINS)

Understanding the Origin and Evolution of the Solar System

1. The Earth, the planet we live on, is part of the Solar System.
2. If we want to know how the Earth formed, we need to understand the origin and evolution of the Solar System.

Teacher Tip:

- Age of Solar System is at **4.6 billion** years old based on radioactive dating of meteorites (Solar System is much younger than the Universe);

INSTRUCTION (35 MINS)

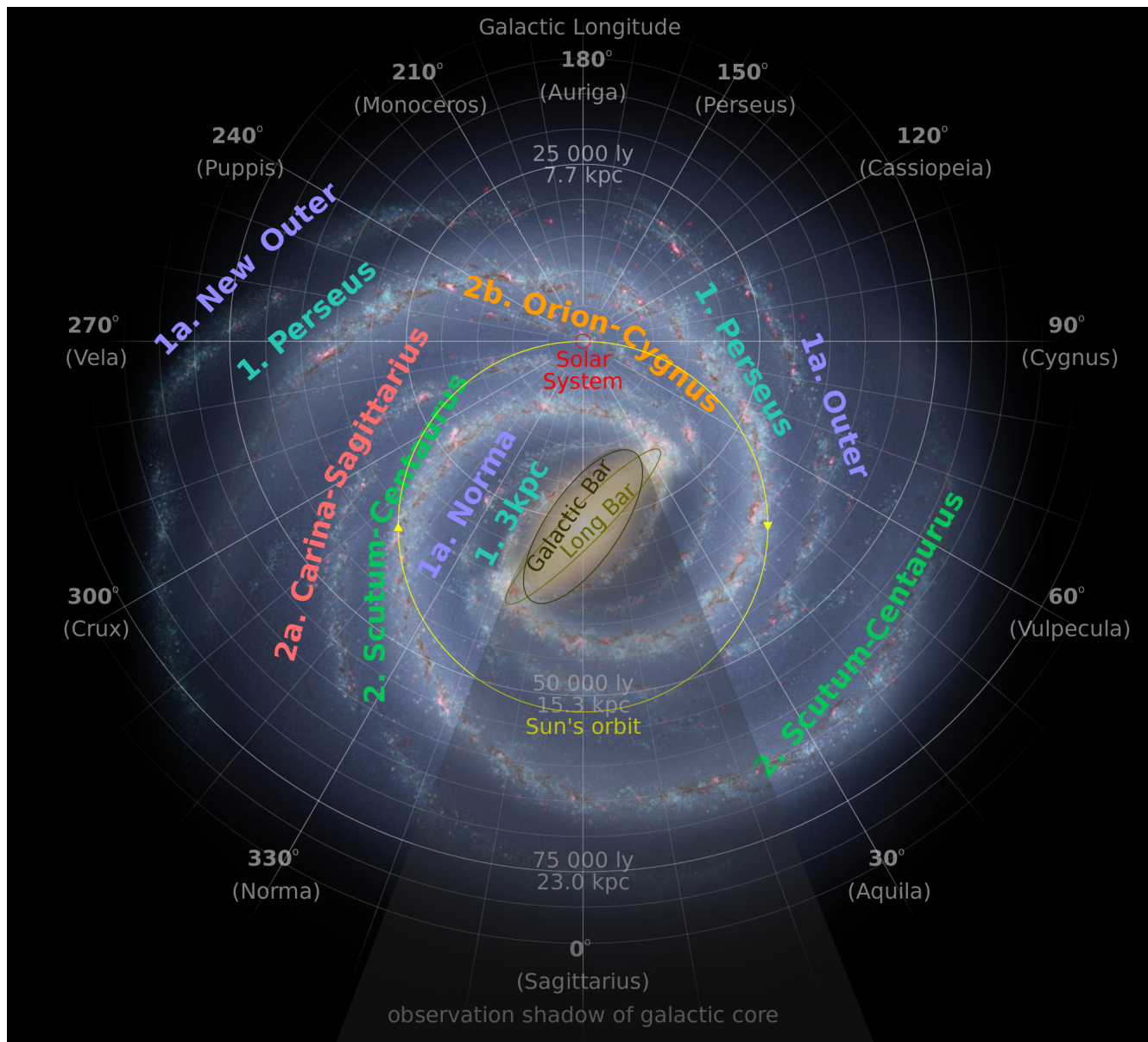
Lecture Proper and Discussion

1. Show to the class the photos of the Milky Way galaxy and discuss the highlights.

Solar System

Overview

- The solar system is located in the Milky Way galaxy—a huge disc- and spiral-shaped aggregation of about at least 100 billion stars and other bodies;
- Its spiral arms rotate around a globular cluster or bulge of many, many stars, at the center of which lies a supermassive blackhole;
- This galaxy is about 100 million light years across ($1 \text{ light year} = 9.4607 \times 10^{12} \text{ km}$);
- The solar system revolves around the galactic center once in about 240 million years;
- The Milky Way is part of the so-called Local Group of galaxies, which in turn is part of the Virgo supercluster of galaxies;
- Based on the assumption that they are remnants of the materials from which they were formed, radioactive dating of meteorites, suggests that the Earth and solar system are 4.6 billion years old. on the assumption that they are remnants of the materials from which they were formed..



Teacher Tip:

- Any hypothesis regarding the origin of the solar system should conform to or explain both large scale and small scale properties of the solar system. Natural forces created and shaped the solar system. The same processes (condensation, accretion, collision and differentiation) are ongoing processes .
- The orderly structure of the Solar System (planets located at regular intervals) and the uniform age of the point to single formation event.
- It would help if there is a table to show these features..comparing and contrasting the different planets.
- Review the learners on of rotation vs revolution.

Source: The Milky Way (https://upload.wikimedia.org/wikipedia/commons/thumb/a/a7/Milky_Way_Arms_ssc2008-10.svg/2000px-Milky_Way_Arms_ssc2008-10.svg.png)

Large Scale Features of the Solar System

1. Much of the mass of the Solar System is concentrated at the center (Sun) while angular momentum is held by the outer planets.
2. Orbits of the planets elliptical and are on the same plane.
3. All planets revolve around the sun.
4. The periods of revolution of the planets increase with increasing distance from the Sun; the innermost planet moves fastest, the outermost, the slowest;
5. All planets are located at regular intervals from the Sun.

Small scale features of the Solar System

6. Most planets rotate prograde
7. Inner terrestrial planets are made of materials with high melting points such as silicates, iron, and nickel. They rotate slower, have thin or no atmosphere, higher densities, and lower contents of volatiles - hydrogen, helium, and noble gases.
8. The outer four planets - Jupiter, Saturn, Uranus and Neptune are called "gas giants" because of the dominance of gases and their larger size. They rotate faster, have thick atmosphere, lower densities, and fluid interiors rich in hydrogen, helium and ices (water, ammonia, methane).

Element Abundance on Earth, Meteorites, and Universe

The table below shows the abundance of elements across bodies in the solar system as compared to abundance in the universe.

- Except for hydrogen, helium, inert gases, and volatiles, the universe and Earth have similar abundance especially for rock and metal elements.
- The sun and the large planets have enough gravity to retain hydrogen and helium. Rare inert gases are too light for the Earth's gravity to retain, thus the low abundance.
- Retention of volatile elements by the Earth is consistent with the idea that some materials that formed the Earth and the solar system were "cold" and solid; otherwise, the volatiles would have been lost. These suggest that the Earth and the solar system could be derived from materials with composition similar to that of the universe.
- The presence of heavy elements such as lead, silver, and uranium on Earth suggests that it was

Teacher Tip:

- **Prograde** - counterclockwise when viewed from above the Earth's North Pole.
- Mercury's orbit around the sun does not conform with the rest of the planets in the solar system. It does not behave according to Newton's Laws.
- The precession or rotation of the orbit is predicted by Newton's theory as being caused by the pull of the planets on one another. The precession of the orbits of all planets except for Mercury's can, in fact, be understood using Newton's equations. But Mercury seemed to be an exception.
- As it orbits the Sun, this planet follows an ellipse, but only approximately: it is found that the point of closest approach of Mercury to the sun does not always occur at the same place as in other planets but that it slowly moves around the sun
- You can choose to skip this part (abundance of elements) if pressed for time.
- If you decide to discuss this part, you may show the table and solicit observations from the students as to the differences/similarities in terms of element composition (Not necessarily absolute amounts). Learners may also provide explanations/implications for their observations.

derived from remnants of a supernova and that the Sun is a second-generation star made by recycling materials.

Abundance of elements

Earth’s origins known mainly from its compositional differences with the entire Universe. Planet-making process modified original cosmic material.

Elemental abundances in Earth vs. Universe (atoms per 10,000 atoms Silicon)					
ROCK MAKERS		CONTINENTAL CRUST	UNIVERSE	METEORITES	WHOLE EARTH
	Si	10,000	10,000	10,000	10,000
	Al	3,000	950	740	740
	Fe	960	6,000	9,300	11,500
	Mg	940	9,100	9,700	9,700
	Ca	1,020	490	520	520
	Na	1,040	440	460	460
	K	540	30	40	40
	Mn	18	70	70	70
	Ti	104	20	20	20
	Ni	13	270	450	750
	P	35	100	60	60
	Cr	19	80	90	90

Expected responses may include:

- A difference between the composition of the Earth's continental crust and the Whole Earth (average composition of the Earth) P The Earth differentiated into compositional layers - crust, mantle, and the core
- Very similar rock and metal elements for Universe and Earth P easy to make Earth if most H and He are removed; sun and large planets have enough mass and gravity to retain H and He
- Inert gases rare on Earth P too light for Earth’s gravity to hold
- Some volatile elements remain P ingredients from which Earth formed were “cold” and solid particles; if hot, would have been lost
- Recall that meteorites are believed to be remnants of materials from which the solar system was derived
- You can ask learners for what theories/ explanations they know about the origin of the solar system.

Elemental abundances in Earth vs. Universe (atoms per 10,000 atoms Silicon)

		CONTINENTAL CRUST	UNIVERSE	METEORITES	WHOLE EARTH
VOLATILES	H	1,400	4.0×10^9		84
	O	29,000	115,000	34,300	34,000
	N	1	66,000		0.2
	C	18	35,000		70
	S	9	3,750	990	1,100
	F	34	16		3
	Cl	4	90		30
INERT GASES	He		3.01×10^7		3.5×10^{-7}
	Ne		86,000		12×10^{-7}
	Ar		1,500		$5,900 \times 10^{-7}$
	Kr		0.51		0.6×10^{-7}

Teacher Tips:

- This is the nature of scientific inquiry. As new data is generated from observations/experimentation, a hypothesis can be revised or even replaced by a new one.
- Present the different hypotheses on the origin of the Solar System in table form. The first column is a summary of the hypothesis. Second column -flaws/drawbacks of the hypothesis.
- You can draw this simple diagram on the board to explain the Nebular Hypothesis.

Origin of the Solar System

Any acceptable scientific thought on the origin of the solar system has to be consistent with and supported by information about it (e.g. large and small scale features, composition). **There will be a need to revise currently accepted ideas should data no longer support them.**

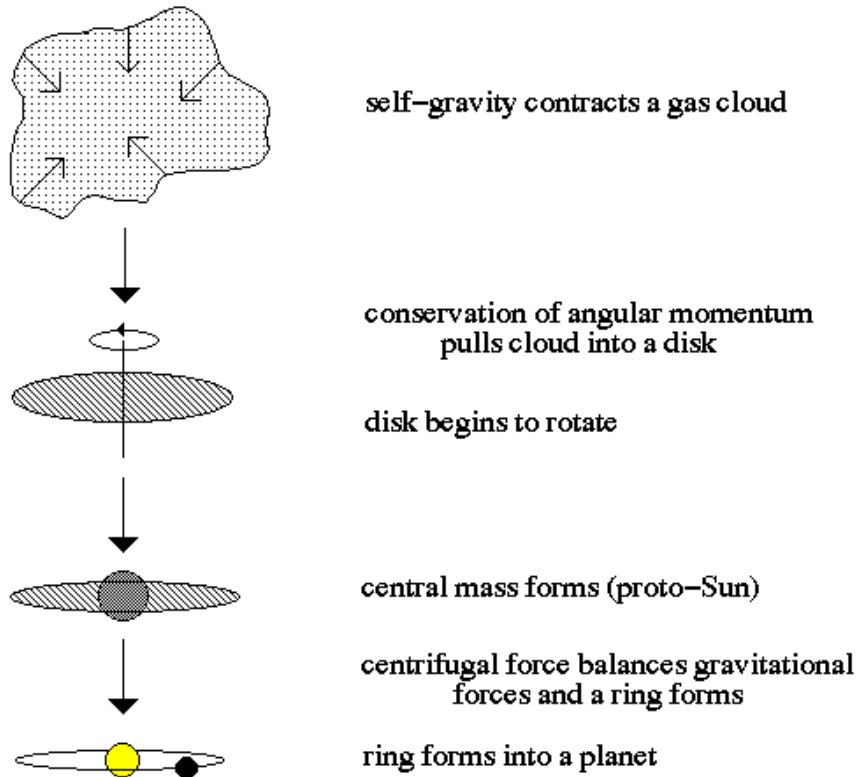
Rival Theories

Many theories have been proposed since about four centuries ago. Each has weaknesses in explaining all characteristics of the solar system. A few are discussed below.

Nebular Hypothesis

In the 1700s Emanuel Swedenborg, Immanuel Kant, and Pierre-Simon Laplace independently thought of a **rotating gaseous cloud that cools and contracts** in the middle to form the sun and the rest into a disc that become the planets. This nebular theory failed to account for the distribution of angular momentum in the solar system.

Nebular Hypothesis



Teacher Tips:

- The common theme of these hypotheses involves an **unlikely encounter** between the Sun and another celestial body (e.g. comet, star, protoplanet, interstellar cloud);
- The two major flaws of this type of hypothesis include: 1) fails to explain how planets are formed (hot gas from the sun/star expands and will not form planets); 2) this type of encounters are extremely rare

Source: Nebular Hypothesis (http://abyss.uoregon.edu/~js/images/nebular_hypothesis.gif)

Encounter Hypotheses:

- Buffon's (1749) **Sun-comet** encounter that sent matter to form planet;
- James Jeans' (1917) **sun-star** encounter that would have drawn from the sun matter that would condense to planets,
- T.C. Chamberlain and F. R. Moulton's (1904) **planetesimal hypothesis** involving a **star much bigger than the Sun passing by the Sun** and draws gaseous filaments from both out of which planetesimals were formed;
- Ray Lyttleton's (1940) sun's companion star colliding with another to form a **proto-planet** that breaks up to form Jupiter and Saturn.
- Otto Schmidt's accretion theory proposed that the Sun passed through **a dense interstellar cloud** and emerged with a dusty, gaseous envelope that eventually became the planets. However, it cannot explain how the planets and satellites were formed. The time required to form the planets exceeds the age of the solar system.
- M.M. Woolfson's capture theory is a variation of James Jeans' near-collision hypothesis. In this scenario, the Sun drags from a near proto-star a filament of material which becomes the planets. Collisions between proto-planets close to the Sun produced the terrestrial planets; condensations in the filament produced the giant planets and their satellites. Different ages for the Sun and planets is predicted by this theory.

Sun - Star interaction

Nobel Prize winner Harold Urey's compositional studies on meteorites in the 1950s and other scientists' work on these objects led to the conclusion that **meteorite constituents have changed very little since the solar system's early history and can give clues about their formation**. The currently accepted theory on the origin of the solar system relies much on information from meteorites.

Protoplanet Hypothesis - Current Hypothesis

- About 4.6 billion years ago, in the Orion arm of the Milky Way galaxy, a slowly-rotating gas and dust cloud dominated by hydrogen and helium starts to contract due to gravity
- As most of the mass moves to the center to eventually become a proto-Sun, the remaining materials form a disc that will eventually become the planets and momentum is transferred outwards.
- Due to collisions, fragments of dust and solid matter begin sticking to each other to form larger and

Teacher Tips:

- Importance of meteorites in determining the age and the origin of the solar system.
- An improvement of the nebular hypothesis based on current knowledge of fluids and states of matter.
- Remind the learner of the comparison of the elemental abundance among the Universe, Meteorites, and the whole Earth
- Accretion and bombardment generate heat (kinetic energy is transformed to heat) which was partly retained by the Earth as **internal heat**

larger bodies from meter to kilometer in size. These **proto-planets** are **accretions** of frozen water, ammonia, methane, silicon, aluminum, iron, and other metals in rock and mineral grains enveloped in hydrogen and helium.

- High-speed collisions with large objects destroys much of the mantle of Mercury, puts Venus in retrograde rotation.
- Collision of the Earth with large object produces the moon. This is supported by the composition of the moon very similar to the Earth's Mantle
- When the proto-Sun is established as a star, its solar wind blasts hydrogen, helium, and volatiles from the inner planets to beyond Mars to form the gas giants leaving behind a system we know today.

Activity (Optional)

Let's Volt In

Activity/game based on Active Accretion NASA's Discovery and New Frontiers Program: http://dawn.jpl.nasa.gov/DawnClassrooms/pdfs/ActiveAccretion_Dawn.pdf

Download or print from CD.

Recent advancement/information on the Solar System

Exploration of Mars

Since the 1960s, the Soviet Union and the U.S. have been sending unmanned probes to the planet Mars with the primary purpose of testing the planet's habitability. The early efforts in the exploration of Mars involved flybys through which spectacular photographs of the Martian surface were taken. The first successful landing and operation on the surface of Mars occurred in 1975 under the Viking program of NASA. Recently, NASA, using high resolution imagery of the surface of Mars, presented evidence of seasonal flow liquid water (in the form of brine - salty water) on the surface of Mars.

Rosetta's Comet

Rosetta is a space probe built by the European Space Agency and launched on 2 March 2004. One of its mission is to rendezvous with and attempt to land a probe (Philae) on a comet in the Kuiper Belt. One of the purpose of the mission is to better understand comets and the early solar systems. Philae landed successfully on comet (67P/Churyumov-Gerasimenko) on 12 November 2014. Analysis of the water (ice) from the comet suggest that its isotopic composition is different from water from Earth.

Teacher Tips:

- The activity/game can be very brief but it would entail preparation and a lot of space (ideally and outdoor activity).
- Surface features (e.g. canyons and drainage system) interpreted from the photographs of the surface Mars suggest the presence of flowing water in the past. (the importance of water to a planet's habitability will be discussed in the next lesson)
- Some scientist speculate that part of the water on the Earth's surface were brought by comets. The difference in isotopic composition of water suggest that this hypothesis is unlikely.
- Recall that objects in the solar system were subject to bombardment and collision early in the evolution of the solar system.
- The presence of craters is proof of this "violent past".
- On Earth, geologic processes have shaped and reshaped the surface removing evidence of cratering

Pluto Flyby

On 14 July 2015, NASA's New Horizon spacecraft provided mankind the first close-up view of the dwarf planet Pluto. Images captured from the flyby revealed a complex terrain - ice mountains and vast crater free plains. The presence of crater free plains suggests recent (last 100 millions of years) of geologic activity.

ENRICHMENT

Is the Solar System unique or rare? What is the possibility of finding a similar system within the Milky Way Galaxy? What about an Earth like planet?

Teacher Tips:

- Recent works are reporting presence of a solar system in the other part of the galaxy. Ask learners to think about the questions and do some research. This can also be used to transition to the next topic - Earth as habitable planet.
- Criteria for assessment of this task may include: Logical discussion on answering the questions with supporting statements based on scientific concepts.

EVALUATION				
	EXCEEDS EXPECTATIONS	MEETS EXPECTATIONS	NEEDS IMPROVEMENT	NOT VISIBLE
Name the different components of the solar system.				
Name the large scale and small scale features of the solar system.				
Discuss the different hypotheses regarding the origin of the solar system and recognizing their weaknesses.				
Discuss the origin and evolution of the solar system based on the most current hypothesis (Proto Planet Hypothesis)				
Enumerate the most recent advancements in the understanding of the Solar System				

Lesson 3: Universe and the Solar System

Content Standard

The learners demonstrate an understanding of the formation of the universe and the solar system.

Learning Competency

The learners shall be able to recognize the uniqueness of Earth, being the only planet in the solar system with properties necessary to support life.

(S11/12ES-la-e-3)

Specific Learning Outcomes

At the end of this lesson, the learners will be able to:

- recognize the difference in the physical and chemical properties between the Earth and its neighboring planets; and
- identify the factors that allow a planet to support life.

LESSON OUTLINE

Introduction	Communicating Learning Objectives	10
Motivation	4 Picture - 1 Word	5
Instruction	Lecture Proper and Discussion	45
Enrichment and Evaluation	Essay on Terraforming	
Materials	Projector or Print-out of Figures	
Resources	(1) http://www.voyagesthroughtime.org/planetary/sample/lesson5/z_act3.htm (2) http://www.voyagesthroughtime.org/planetary/sample/lesson5/pdf/goldilocks.pdf (3) http://www.voyagesthroughtime.org/planetary/sample/lesson5/pdf/5_3_1sas_crashland.pdf (4) https://btc.montana.edu/ceres/html/Habitat/habitablezone.htm (5) http://nssdc.gsfc.nasa.gov/planetary/factsheet/	

INTRODUCTION (10 MINS)

1. Introduce the following learning objectives :
2. At the end of this lesson, the learners will be able to:
 - A. Recognize the difference in the physical and chemical properties between the Earth and its neighboring planets.
 - B. Identify the factors that allow a planet to support life.
3. Review previous lesson on the Solar System:
 - A. Origin
 - B. Components
 - C. Terrestrial vs Gas Planets

MOTIVATION (5 MINS)

Four pictures one word

Ask the students to guess the four letter word. "L I F E"

Man's failure to protect the environment and therefore LIFE here on Earth is perhaps due to:

1. Inability to recognize the full consequence of his/her actions;
2. Lack of appreciation of how truly unique the Earth is.

The humanity's failure to protect the environment and **life** here on Earth is likely due to the following:

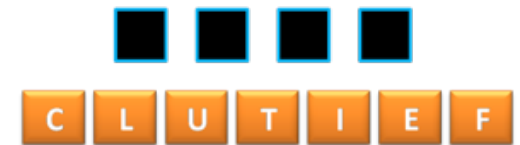
3. Inability to recognize the full consequence of his/her actions
4. Lack of appreciation of how truly unique the Earth is

Teacher tip

The concept of the Earth as a system and the interconnectivity of its components will be discussed in the succeeding lesson.

Teacher tip

Teacher can create his or her own 4 Picture 1 Word puzzle. Use images that the learners can easily relate to.



Teacher tip

The concept of the Earth as a system and the interconnectivity of its components will be discussed in the succeeding lesson.

INSTRUCTION/PRACTICE (45 MINS)

Activity 1: Compare and Contrast. What are the similarities and differences among these three terrestrial planets?

Venus

Earth

Mars

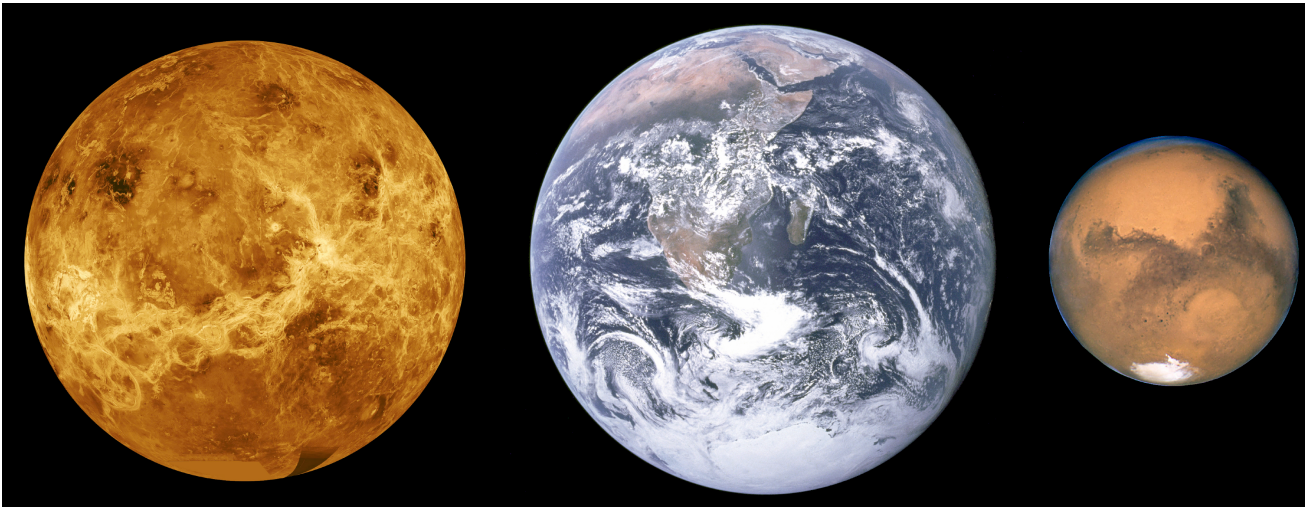


Figure 1. Venus, Earth, and Mars. Images from NASA.

1. Print and cut-out photographs of terrestrial planets Venus, Earth, and Mars. Place photographs side by side.
2. Divide the class into groups of 3 to 5. Give each group a copy of Table 1 for reference. Ask each group to write down on a piece of paper similarities and differences among the planets. Give the students 15 minutes to complete the task.
3. Ask the learners to provide possible explanations for their observations using the information in Table 2, together with previous knowledge about the planets.
4. After the task, ask a representative from each group to present their observations.

Teacher Tips:

- To save time, prepare before the class starts.
- Try to print colored photographs in hard paper (so it can be used several times). Print the photographs in the correct scale.
- Alternatively, the teacher may opt to post on the blackboard the contents of Table 2 instead of giving out copies to the learners.

Possible responses may include:

- The color blue for Earth is significant - liquid water. The size difference/similarity is also important.
- Similar size and mass of Venus and Earth. Mars is about half the Earth's size.
- All the three planets have spheroidal shape.
- Rows color coded to indicate relationship.
- **Escape velocity** - minimum speed an object needs to escape a planet's pull of gravity.
- **Surface pressure** - atmospheric pressure at a location on the surface of the planet. It is proportional to the mass of air above the location
- **Temperature if no GHG** - this would be the temperature of the planet without the warming effect of green house gases. Note that the temperature of the Earth would be ~ 18 °C lower without green house warming.
- Emphasize to the students that the green house effect is not necessarily undesirable. It is run-away green house effect which we would like to avoid (e.g. Venus).

Table 1. Venus, Earth, Mars Comparison(modified from <http://nssdc.gsfc.nasa.gov/planetary/factsheet/>)

	VENUS	EARTH	MARS
Mass (1,024 kg)	4.87	5.97	0.642
Diameter (km)	12,104	12,756	6,792
Density (kg/m ³)	5,243	5,514	3,933
Gravity (m/s ²)	8.9	9.8	3.7
Escape Velocity (km/s)	10.4	11.2	5
Surface Pressure (bars)	92	1	0.01
Composition of Atmosphere	96% CO ₂ 3.5% N	77% N 21% O ₂ 1% Ar	95 % CO ₂ 2.7% N 1.6% Ar
Major Greenhouse Gases (GHG)	CO ₂	CO ₂ H ₂ O	CO ₂
Mean Temperature (C)	464	15	-65
Temperature if no GHG	-46	-18	-57
Change in Temperature (C) due to GHG	+ 523	+ 33	+ 10
Distance from Sun (10 ⁶ km)	108.2	149.6	227.9
Orbital Period (days)	224.7	365.2	687
Orbital Velocity (km/s)	35	29.8	24.1
Length of Day (hours)	2,802	24	24.7
Global Magnetic Field	No	Yes	No

Teacher Tips:

- Rows color coded to indicate relationship.
- **Escape velocity** - minimum speed an object needs to escape a planet's pull of gravity.
- **Surface pressure** - atmospheric pressure at a location on the surface of the planet. It is proportional to the mass of air above the location
- **Temperature if no GHG** - this would be the temperature of the planet without the warming effect of green house gases. Note that the temperature of the Earth would be ~ 18 °C lower without green house warming.
- Emphasize to the students that the green house effect is not necessarily undesirable. It is run-away green house effect which we would like to avoid (e.g. Venus).
- Ask the students what is the consequence if there was not GHG effect.
- **Length of day** - a function of rotational speed.
- The **Earth's magnetic field** is believed to be the consequence of the presence of a solid metallic inner core and a liquid metallic outer core. (Topic to be discussed in succeeding lessons - Earth's Interior.
- The ability of a planet to retain its **internal heat** is proportional to its **size**. Mars may have lost much of its internal heat very early in its evolution.
- A planet's **temperature** is a function of distance from the Sun but is modified by the amount of greenhouse warming.

1. Venus, Earth, and Mars are part of the inner terrestrial or "rocky" planets. Their composition and densities are not too different from each other.
2. Venus is considered to be the Earth's twin planet. It has a very similar size and mass with the Earth. Mars is about half the Earth's size.
3. Orbital period and velocity are related to the planet's distance from the sun. Among the three planet, Venus is the nearest and Mars is the farthest from the Sun.
4. Rotational speed of Earth and Mars are very similar. Rotational speed of Venus is extremely slow.
5. Abundance of liquid water on Earth, hence the blue color. The Earth is a habitable planet.

Activity 2. Interstellar Crash Landing

1. Ask students what factors would a planet habitable. Learners should try to elaborate on their responses. (adapted from: http://www.voyagethroughtime.org/planetary/sample/lesson5/pdf/5_3_1sas_crashland.pdf)
2. Provide a copy of Table 2 - "Factors that Make a Planet Habitable" to each of the group (can be the same grouping as Activity 1). Ask students to read the document carefully and compare their answers they have given at the start of the activity

Table 2. Factors that Make a Planet Habitable (http://www.lpi.usra.edu/education/explore/our_place/hab_ref_table.pdf)

Teacher Tips:

- **Water** - in the liquid form, turns out to be one of the most important prerequisites for life as we know it.
- There is recent evidence that liquid water, in the form of brine (salty water) flows intermittently on the surface of Mars.
- **Thermophiles** - bacteria that can tolerate extreme temperatures (41 to 122 °C) commonly associated with hot springs and deep-sea hydrothermal vents. Life, in general can tolerate a wide range of temperature conditions. The temperature range that allows water to exist in the liquid state is the over-riding factor.
- Planets should have **sufficient size** to hold a **significant atmosphere**. The composition of the atmosphere, specifically the amount of **green house gases**, influences the planet **surface temperature**.
- The amount of **solar radiation** that a planet receives is primarily a function of distance from the sun. **Sunlight** is essential for **photosynthesis** but some organism are able to extract energy from other sources (**chemosynthetic organisms**).
- A system that will be able to constantly supply nutrients to organisms is important to sustain life. On Earth, nutrients are cycled through the hydrologic cycle and plate tectonics (volcanism)
- Internal heat drives plate tectonics. The ability of a planet to maintain internal heat is related to size.
- The document/table can be downloaded from http://www.lpi.usra.edu/education/explore/our_place/hab_ref_table.pdf

Factors that make a Planet Habitable	Not Enough of the Factor	Just Right	Too Much of the Factor	Situation in the Solar System
Temperature influences how quickly atoms and molecules move.	Low temperatures cause chemicals to react slowly, which interferes with the reactions necessary for life. It can also cause the freezing of water, making liquid water unavailable.	Life seems to be limited to a temperature range of -15oC to 115oC. In this range, liquid water can still exist under certain conditions.	At about 125oC, protein and carbohydrate molecules, and the genetic material (e.g., DNA and RNA) start to break apart. Also, high temperatures cause the quick evaporation of water.	Surface: only the Earth's surface is in this temperature range. Sub-surface: the interior of the solid planets and moons may be in this temperature range.
Atmosphere Traps heat, shields the surface from harmful radiation, and provides chemicals needed for life, such as nitrogen and carbon dioxide.	Small planets and moons have insufficient gravity to hold an atmosphere. The gas molecules escape to space, leaving the planet or moon without an insulating blanket or a protective shield.	Earth & Venus are the right size to hold a sufficient-sized atmosphere. Earth's atmosphere is about 100 miles thick. It keeps the surface warm & protects it from radiation & small- to medium-sized meteorites.	Venus's atmosphere is 100 times thicker than Earth's. It is made almost entirely of greenhouse gasses, making the surface too hot for life. The four giant planets are completely made of gas.	Of the solid planets & moons, only Earth, Venus, & Titan have significant atmospheres. Mars' atmosphere is about 1/100th that of Earth's, too small for significant insulation or shielding.
Energy Organisms use light or chemical energy to run their life processes.	When there is too little sunlight or too few of the chemicals that provide energy to cells, such as iron or sulfur, organisms die.	With a steady input of either light or chemical energy, cells can run the chemical reactions necessary for life.	Light energy is a problem if it makes a planet too hot or if there are too many harmful rays, such as ultraviolet. Too many energy-rich chemicals is not a problem	Surface: The inner planets get too much sunlight for life. The outer planets get too little. Sub-surface: Most solid planets & moons have energy-rich chemicals.
Nutrients Used to build and maintain an organism's body.	Without chemicals to make proteins & carbohydrates, organisms cannot grow. Planets without systems to deliver nutrients to its organisms (e.g., a water cycle or volcanic activity) cannot support life. Also, when nutrients are spread so thin that they are hard to obtain, such as on a gas planet, life cannot exist.	All solid planets & moons have the same general chemical makeup, so nutrients are present. Those with a water cycle or volcanic activity can transport and replenish the chemicals required by living organisms.	Too many nutrients are not a problem. However, too active a circulation system, such as the constant volcanism on Jupiter's moon, Io, or the churning atmospheres of the gas planets, interferes with an organism's ability to get enough nutrients.	Surface: Earth has a water cycle, an atmosphere, and volcanoes to circulate nutrients. Venus, Titan, Io, and Mars have nutrients and ways to circulate them to organisms. Sub-surface: Any planet or moon with sub-surface water or molten rock can circulate and replenish nutrients for organisms

1. You may also require the learners to include a sketch/diagram of how they think their habitable planet/moon would look like based on the factors for habitable planet/moon.
2. Ask the students to imagine themselves in an interstellar voyage. Their spaceship suffers mechanical problems and will be forced to land. Fortunately they are passing through the YanibSystem, which is composed of a sun-like star surrounded by seven planets, some of which have moons. The profiles of planets and moons of the Yanib System are listed on Table 3 (Provide each group a copy of Table 3). Students are to decide the best place to land their ship.
3. Ask students to write down on a piece of paper their choice of planet or moon. Reasons for their choice should also be written down. Reasons why they did not choose the other planets should also be included.

Table 3 Profiles of Planets and Moons of Yanib System. Modified from: http://www.voyagesthroughtime.org/planetary/sample/lesson5/pdf/5_3_1sas_crashland.pdf

Planet 1 (closest to the star) Mass: 1.5 (Earth = 1) Tectonics: Active volcanoes and seismic activity detected Atmosphere: CO₂, N, and H₂O Ave. Temperature: 651°C Description: Thick clouds surround the planet. No surface is visible through the clouds.	Planet 2 Mass: 0.5 Tectonics: No activity detected Atmosphere: Thin CO₂ atmosphere detected Average Temperature: 10°C Description: Polar ice caps, dry riverbeds	Planet 3 Mass: 1 Tectonics: Active volcanoes and seismic activity detected. Atmosphere: CO₂, H₂O Temperature: 30 °C Description: Liquid water oceans cover much of the surface. Volcanic island chains make up most of the dry land.	Planet 4 Mass: 1.5 Tectonics: Active volcanoes and seismic activity detected Atmosphere: N, O₂, and ozone layer Average Temperature: 2°C Description: Cold oceans, covered with ice along much of the globe, some open water around equator
Planet 5 Gas Giant with one large moon. Moon: Sulfur dioxide (SO₂) atmosphere. Many volcanoes and hot springs on surface. Temperatures in hot spots can be up to 600°C. Other spots away from volcanic heat can get as low in temperature as 145°C.	Planet 6 Gas giant with four large, rocky satellites (moons). Moons have no appreciable atmosphere. Ice detectable on one.	Planet 7 (furthest from the star) Gas giant with two large moons. Moon 1: Thick methane atmosphere with pressure high enough to keep a potential methane ocean liquid underneath. Temperature: -200 °C Moon 2: Covered in water ice. Ice appears cracked and re-frozen in parts, indicating a potential liquid ocean underneath. Surface temperature -100 °C.	

ENRICHMENT

Terraforming Mars

Have the learners write a 200 word report/essay on the following topic: 'Can man alter Mars environment to make it more suitable for human habitation? How?'

Teacher tip

- To **terraform** means to transform another planet to resemble the Earth in several aspects, specifically the ability to support life.
- Use the following criteria in assessing this assignment:
 - Logic and consistency in the arguments
 - Valid and consistent scientific concepts to support the answer

	NOT VISIBLE	NEEDS IMPROVEMENT	MEETS EXPECTATIONS	EXCEEDS EXPECTATIONS
Identify similarities and differences among the three planets, namely Venus, Earth, and Mars.				
Explain the impact of planet size to gravity, internal heat, and atmosphere of the planet.				
Identify factors that influence a planet's temperature.				
Explain factors that make a planet habitable.				
Explain why the presence of liquid water is important to life				

Lesson 4: Earth Subsystems

Content Standard

The learners the subsystems (geosphere, hydrosphere, atmosphere, and biosphere) that make up the Earth.

Learning Competency

The learners shall be able to explain that the Earth consists of four subsystems, across whose boundaries matter and energy flow **(S11/12ES-Ia-e-4)** and show the contributions of personalities/people on the understanding of Earth Systems **(S11/12ES-Ia-e-6)**.

Specific Learning Outcomes

At the end of this lesson, the learners will be able to:

- define the concept of a system;
- recognize the Earth as a system composed of subsystems; and
- discuss the historical development of the concept of Earth System.

LESSON OUTLINE

Pre-Class Activity	Optional Activities based on Class Setting	30
Introduction	Communicating Learning Objectives	5
Motivation	Class Sharing	5
Instruction	The Earth System	30
Enrichment and Evaluation	Take Home Essay	20

Materials

Pencil/Drawing Material, A4 or Letter size Paper, Clip Board or any flat surface that can be used for drawing

Resources

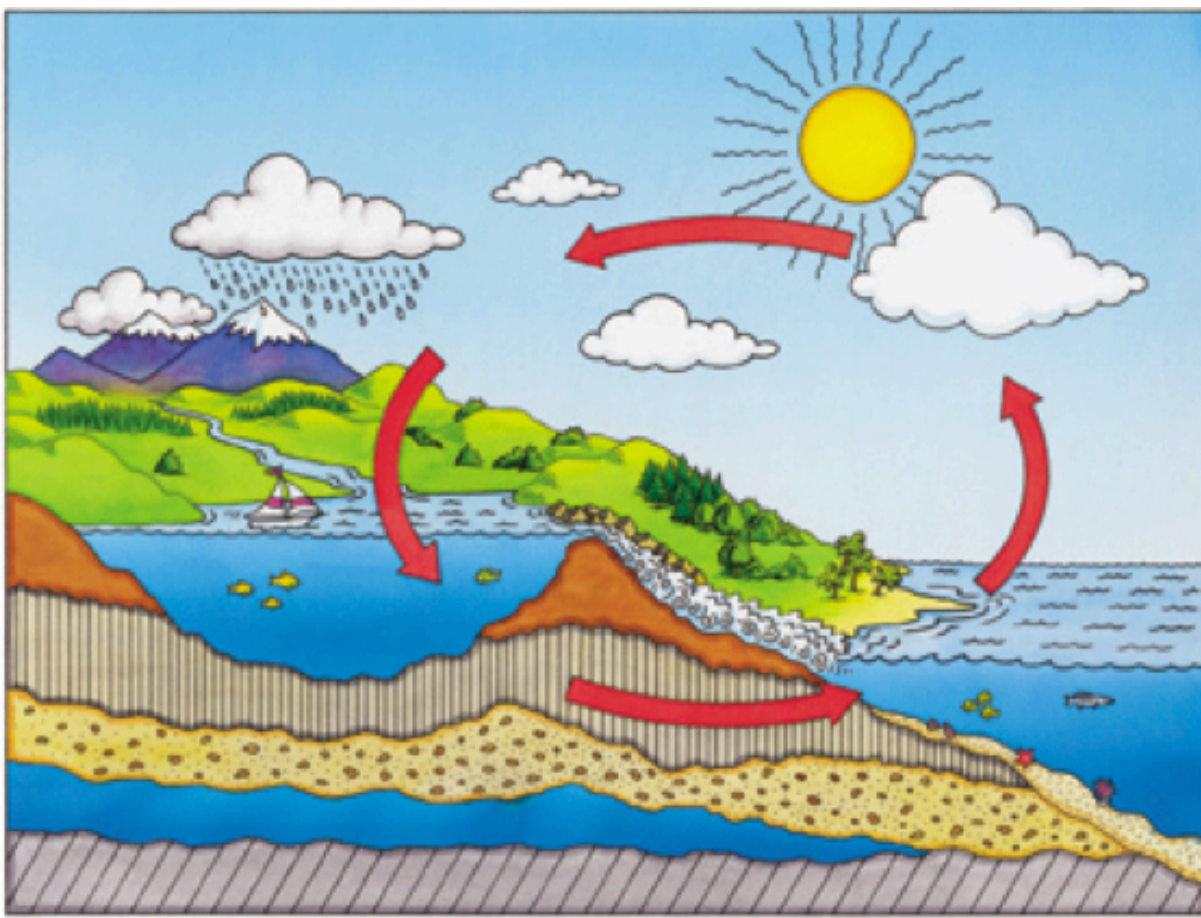
- (1) Earth Systems. <http://serc.carleton.edu/earthlabs/climate/index.html>
<https://www.google.com.ph/webhp?sourceid=chrome-instant&ion=1&espv=2&ie=UTF-8#q=earth+systems>
- (2) Earth Systems. http://www.esrl.noaa.gov/gmd/outreach/lesson_plans/Teacher%20Background%20Information-%20The%20Major%20Earth%20Spheres.pdf
- (3) Hydrologic Cycle. http://www.esrl.noaa.gov/gmd/outreach/lesson_plans/The%20Hydrologic%20Cycle.pdf
- (4) El Niño Phenomenon. <http://www.esrl.noaa.gov/gmd/obop/mlo/educationcenter/students/brochures%20and%20diagrams/noaa%20publications/El%20Nino%20Fact%20Sheet.pdf>
- (5) Video Daisy World Model. <https://www.youtube.com/watch?v=cW4JTHz1aRg>

PRE-CLASS ACTIVITY (30 MINS)

1. Perform either one of the following pre-class activities (30 minutes).
 - Option 1 (This option is recommended for schools in a non-urban setting.)
 - Using a pencil and a piece of paper, have the learners draw or illustrate the field area. Take note of the presence of vegetation, soil cover, wildlife, rockout-crops, and bodies of water. Ask the learners to think how energy and mass are transferred in the different components of the area.
 - Option 2 (This option is recommended for schools in an urban setting.)
 - Together with the learners, label the different processes and phases of water involved in the water cycle.

Teacher tip

- Check your immediate surrounding for an appropriate field area, preferably with trees or vegetation, and pond, lake, or stream.
- Before bringing the learners to the field area, check for potential hazards. If applicable, the learners should be properly warned about safety precautionary measures.
- For schools in urban areas without open spaces, choose option 2.



Teacher tip

- The concept of ecosystems has been discussed in pre-SHS biology. Emphasize the definition of the word interaction.
- Most of the terms in this lesson have been introduced in previous science subjects.
- Help the learners integrate the concepts that will be introduced.

Figure 1: Hydrologic Cycle (w/o labels)

Image Source: http://3.bp.blogspot.com/_YTb6Zb1Ju0o/TPMzp32R5aI/AAAAAAAAALg/vnul9ZgWt0M/s1600/WaterCycleArt.jpg

- Use the following terms to complete the cycle:
 - condensation
 - precipitation
 - evaporation
 - transpiration
 - infiltration
 - surface run-off

INTRODUCTION (5 MINS)

1. Introduce the following learning objectives using any of the suggested protocols(Verbatim, Own Words, Read-aloud)
 - A. I can identify and explain each of the subsystems of the Earth;
 - B. I can explain how these subsystems interact.
 - C. I am familiar with the historic development of the concept of "Earth System"
2. Ask the students what they remember about the concept of Ecosystems.

MOTIVATION (5 MINS)

1. Ask the students what they know or have experienced regarding El Niño.
2. Use the Figure 2, briefly explain the El Niño phenomenon. Emphasize that it starts with the unusual warming of the central Pacific Ocean accompanied by the weakening of the trade winds. The warming of the central Pacific Ocean results to an eastward shift of the low pressure area (away from the Indo Pacific).

Teacher tip

- The concept of Ecosystems has been discussed in middle high school biology. Emphasize the word "interaction".
- Most of the terms to be used in this lesson have been introduced in previous science subjects.
- The challenge to the teacher is to help students to integrate concepts and explore relationships.
- Most of the answers will describe atmospheric conditions e.g. hot and dry, no rain, water crisis etc.
- Point out that an El Niño is not limited to atmospheric conditions. It is the result of ocean (hydrosphere)-atmosphere interaction.
- The subsystems of the Earth (Atmosphere, Hydrosphere, Biosphere, and Lithosphere) interact with each other.

THE EL NIÑO PHENOMENON

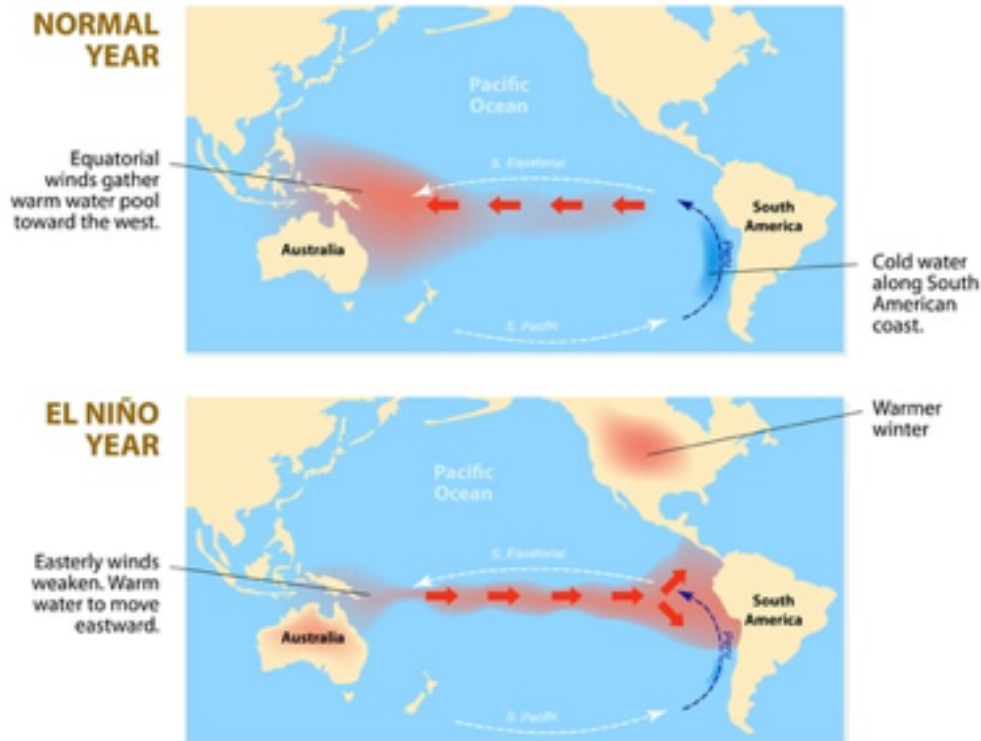


Figure 2. El Niño phenomenon

Source: <http://images.listlandcom.netdna-cdn.com/wp-content/uploads/2015/09/The-El-Nino-Phenomenon-explained-in-a-nice-little-graphic.jpg>

Teacher tip

- Most of the answers will describe the atmospheric conditions during El Niño (e.g. hot and dry, no rain, water crisis, etc.)
- Emphasize that El Niño is not limited to atmospheric conditions. It is the result of hydrosphere (ocean)-atmosphere interaction.
- The subsystems of the Earth (atmosphere, hydrosphere, biosphere, and lithosphere) interact with each other.

3. Explain the origin of the term '**El Niño**' as a decrease in fish catch off the coast of Peru near Christmas time. Emphasize that this is a biologic response.

INSTRUCTION (30 MINS)

1. Definition of a System
 - A set of interconnected components that are interacting to form a unified whole.
2. Components or subsystems of the Earth System.
 - Use a projector or draw on the board a diagram (below) to enumerate the subsystems of the Earth.

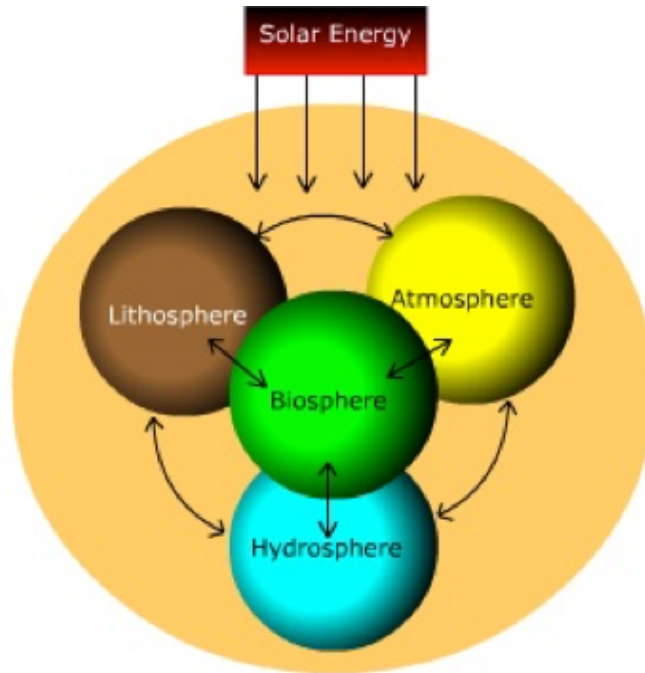


Figure 3: The Earth system. (Source: <https://www.earthonlinemedia.com>)

Teacher tips:

- Give the government as an example. Inquire about the three branches of the government (executive, judiciary, and legislative). Explain that these three branches are independent and have their respective mandates or functions. A government can only succeed if all three branches are able to perform their respective functions.
 - The arrows in the diagram indicate the interaction among the components.
 - A closed system is a system in which there is only an exchange of heat or energy and no exchange of matter.
3. Explain that the Earth system is essentially a closed system. It receives energy from the sun and returns some of this energy to space.

4. Introduce the term **atmosphere**.

- The atmosphere is the thin gaseous layer that envelopes the lithosphere.
- The present atmosphere is composed of 78% nitrogen (N), 21% oxygen (O₂), 0.9% argon, and trace amount of other gases.
- One of the most important processes by which the heat on the Earth's surface is redistributed is through atmospheric circulation.
- There is also a constant exchange of heat and moisture between the atmosphere and the hydrosphere through the hydrologic cycle.

5. Introduce the term **lithosphere**.

- The lithosphere includes the rocks of the crust and mantle, the metallic liquid outer core, and the solid metallic inner core.
- Briefly discuss the Plate Tectonics as an important process shaping the surface of the Earth. The primary driving mechanism is the Earth's internal heat, such as that in mantle convection.

6. Introduce the term **biosphere**.

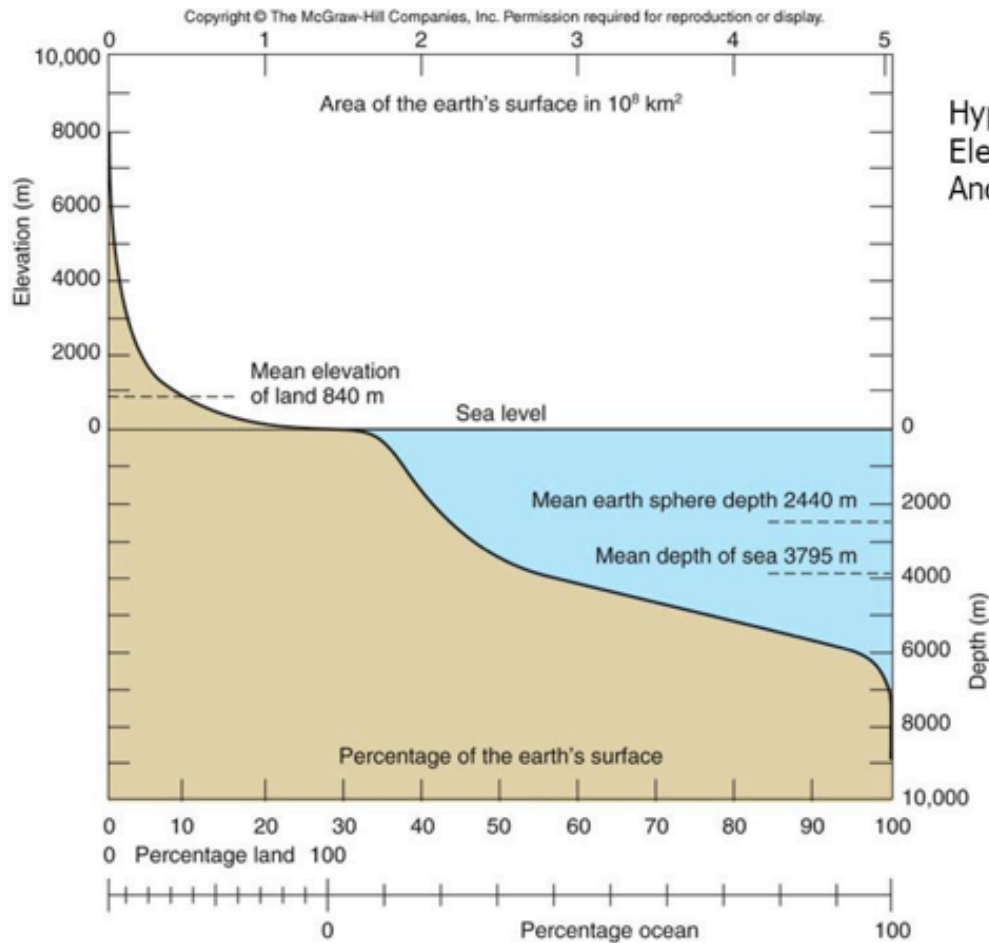
- The biosphere is the set of all life forms on Earth.
- It covers all ecosystems—from the soil to the rainforest, from mangroves to coral reefs, and from the plankton-rich ocean surface to the deep sea.
- For the majority of life on Earth, the base of the food chain comprises photosynthetic organisms. During **photosynthesis**, CO₂ is sequestered from the atmosphere, while oxygen is released as a byproduct. The biosphere is a CO₂ sink, and therefore, an important part of the **carbon cycle**.
- Sunlight is not necessary for life.

7. Introduce the term **hydrosphere**.

- About 70% of the Earth is covered with liquid water (hydrosphere) and much of it is in the form of ocean water (Figure 3).
- Only 3% of Earth's water is fresh: two-thirds are in the form of ice, and the remaining one-third is present in streams, lakes, and groundwater.

Teacher tips:

- Describe each subsystem of the Earth.
- Warm air converges and rises to form low-pressure zones. Low-pressure areas are associated with increased precipitation. By contrast, cold air descends to form high-pressure regions (dry regions).
- The concept of Plate Tectonics will be discussed in detail in the succeeding lessons (Internal Structure of the Earth)
- The carbon cycle is the process by which carbon is transferred among the atmosphere, oceans, soil, and living organisms.
- Isolated and complex ecosystems thrive in the deep sea floor at depths beyond the reach of sunlight. The base of the food chain for such ecosystems is called **chemosynthetic** organisms. Instead of sunlight, these organisms use energy from **hydrothermal vents** or **methane seeps** (methane seeping through rocks and sediments) to produce simple sugars.



Hypsographic Curve
Elevation areas above
And below sea-level

Teacher tips:

- The hypsographic curve is a graphical representation of the proportion of land at various elevations (meters above or below sea level)
- Make sure that the students understand what the X and Y axis represents. To test comprehension, ask the students what proportion of the Earth's surface is about 4000m below sea level (~ 60 %)
- The hydrologic cycle (water cycle) has been partly discussed in Grade 4 (water in the environment) and Grade 8 (Ecosystems).
- Through the process of weathering and erosion. the hydrologic cycle is another important process contributing to the shaping and reshaping the surface of the Earth. This is an important link between the hydrosphere, atmosphere and lithosphere that the student should be able to identify.

- The oceans are important sinks for CO_2 through direct exchange with the atmosphere and indirectly through the weathering of rocks.
- Heat is absorbed and redistributed on the surface of the Earth through ocean circulation.

3. The origin of the systems approach to the study of the Earth

- One of the first scientist to push for a more integrated or holistic approach in the understanding of the universe (and by extension the Earth) was **Friedrich Wilhelm Heinrich Alexander von Humboldt**. He considered the universe as one interacting entity.
- The term "**biosphere**" was popularized by **Vladimir Vernadsky** (1863-1945), a Russian - Ukranian scientist who hypothesized that life is a geological force that shapes the Earth.
- In the 1970s, the **Gaia Hypothesis** was jointly developed by James Lovelock, an English scientist/naturalist, and Lynn Margulis, an American microbiologist. According to the Gaia Hypothesis. the biosphere is a self-regulating system that is capable of controlling its physical and chemical environment.
- In 1983, **NASA** advisory council established the **Earth Systems Science Committee**. The committee, chaired by **Moustafa Chahine**, published a ground breaking report *Earth System Science: A Program For Global Change* in 1988. For the first time, scientist were able to demonstrate how the many systems interact.

Teacher tips:

- To illustrate how a living organism is capable of self regulation, ask the students how their bodies react to outside temperature.
- When it is hot, we sweat. Evaporation of the sweat cools down our skin. When it is cold, we shiver. The mechanical shaking of the body when we shiver releases heat
- Use the pre-lecture drawing exercise for schools with open spaces (option 1); else, use the hydrologic cycle diagram

PRACTICE (20 MINS)

1. Using the illustration diagram (option 1 or 2), identify how energy and mass is exchanged among the subsystems. Maybe use different types of line .boxes to differentiate between matter / materials and energy?
2. Use arrows to indicate interaction between components.

ENRICHMENT

1. James Lovelock used the "Daisy World Model" to illustrate how the biosphere is capable of regulating its environment.
2. Ask the students to research and write a two page report (50 to 100 words, with illustrations) on the "Daisy World Model" of James Lovelock.

Teacher tips:

A simple explanation of the Daisy World Model can be viewed in: <https://www.youtube.com/watch?v=cW4JTHz1aRg>

	EVALUATION			
	NOT VISIBLE	NEEDS IMPROVEMENT	MEETS EXPECTATIONS	EXCEEDS EXPECTATIONS
Understands the concept of a system.				
Can describe the different components or subsystems of the Earth System.				
Can identify and explain how mass and energy is exchanged among the components of a system.				
Essay is relevant to the assigned topic and written logically and clearly.				