PISCATAWAY
TOWNSHIP SCHOOLS

Dr. Frank Ranelli
Superintendent of Schools

Content Area: Marine Biology
Grade Span: 9-12
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COURSE OVERVIEW

Description

This is an elective course in Marine Biology for 2.5 credits, which is intended to introduce students to the branch of the biological sciences that focuses on marine systems. Students will study many of the organisms in this unique world and will also explore factors and environmental issues that influence and control the abundance and distribution of species in this diverse community. Students in this course will be introduced to the interrelationships of marine ecosystems. They will be able to identify and analyze both natural and human-made environmental problems. Students will be expected to think critically about all aspects of marine science. Laboratory-based investigations, student–centered collaborations, and hands-on dissections will be used in this course to illustrate various living and non-living aspects of the biology of the oceans.

Goals

Students will demonstrate the ability to explain the scope and methodology of marine science and the role that scientific investigations play in the search for scientific understanding of the sea. Students will demonstrate the ability to apply the basic principles of biology to marine organisms.

Scope and Sequence

Unit	Topic	Length
1	MARINE BIOLOGY INTRODUCTION	5
2	COASTAL ECOSYSTEMS	20
3	OPEN OCEAN ECOSYSTEMS	10
4	DEEP SEA BENTHIC ECOSYSTEMS	10

UNIT 1: MARINE BIOLOGY INTRODUCTION

Summary and Rationale

This unit covers the introduction to the ecology of the ocean and its importance to humans. Students will gain important skills in reading scientific literature, mastering the scientific method, and synthesizing their understanding of complex scientific issues. Students will study many of the organisms in this unique world and will also explore factors and environmental issues that influence and control the abundance and distribution of species in this community.

Recommended Pacing

5 blocks

State Standards

HS-PS1-5. Apply scientific principles and evidence to provide an explanation about the effects of changing the temperature or concentration of the reacting particles on the rate at which a reaction occurs.

Clarification Statement	Emphasis is on student reasoning that focuses on the number and energy of collisions between molecules.
Assessment Boundary	Assessment is limited to simple reactions in which there are only two reactants; evidence from temperature, concentration, and rate data; and qualitative relationships between rate and temperature.

HS-ESS2-5. Plan and conduct an investigation of the properties of water and its effects on Earth materials and surface processes.

Clarification Statement	Emphasis is on mechanical and chemical investigations with water and a variety of solid materials to provide the evidence for connections between the hydrologic cycle and system interactions commonly known as the rock cycle. Examples of mechanical investigations include stream transportation and deposition using a stream table, erosion using variations in soil moisture content, or frost wedging by the expansion of water as it freezes. Examples of chemical investigations include chemical weathering and recrystallization (by New Jersey Department of Education January 2022 Page 187 of 200testing the solubility of different materials) or melt generation (by examining how water lowers the melting temperature of most solids).

Instructional Focus

Unit Enduring Understandings (Cross Cutting Concepts)

- **Patterns** Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena.
- **Structure and Function** The functions and properties of natural and designed objects and systems can be inferred from their overall structure, the way their components are shaped and used, and the molecular substructures of its various materials.

Unit Essential Questions

- What is the distribution of water on the earth?
- How do the unique properties of water allow life to exist?
- What is the relationship between salinity and density?

Objectives

Students will know (DCIs):

PS1.B: Chemical Reactions

Chemical processes, their rates, and whether or not energy is stored or released can be understood in terms of the collisions of molecules and the rearrangements of atoms into new molecules, with consequent changes in the sum of all bond energies in the set of molecules that are matched by changes in kinetic energy.

ESS2.C: The Roles of Water in Earth's Surface Processes

The abundance of liquid water on Earth’s surface and its unique combination of physical and chemical properties are central to the planet’s dynamics. These properties include water’s exceptional capacity to absorb, store, and release large amounts of

energy, transmit sunlight, expand upon freezing, dissolve and transport materials, and lower the viscosities and melting points of rocks.

Students will be able to (SEPs):

- Constructing Explanations and Designing Solutions
- Planning and Carrying Out Investigations

UNIT 2: COASTAL ECOSYSTEMS

Summary and Rationale

This unit includes Intertidal, Continental Shelf, Estuaries, Reefs, and Polar ecosystems. Students will explore how the biotic and abiotic factors of these communities interact with one another, while discovering the impact humans have on the environment. Students will gain important skills in reading scientific literature, mastering the scientific method, and synthesizing their understanding of complex scientific issues. Students will study many of the organisms in this unique world and will also explore factors and environmental issues that influence and control the abundance and distribution of species in this community.

Recommended Pacing

20 blocks

State Standards

HS-LS1-2. Develop and use a model to illustrate the hierarchical organization of interacting systems that provide specific functions within multicellular organisms.	
Clarification Statement	Emphasis is on functions at the organism system level such as nutrient uptake, water delivery, and organism movement in response to neural stimuli. An example of an interacting system could be an artery depending on the proper function of elastic tissue and smooth muscle to regulate and deliver the proper amount of blood within the circulatory system.
Assessment Boundary	Assessment does not include interactions and functions at the molecular or chemical reaction level.
HS-LS2-4. Use mathematical representations to support claims for the cycling of matter and flow of energy among organisms in an ecosystem.	
Clarification Statement	Emphasis is on using a mathematical model of stored energy in biomass to describe the transfer of energy from one trophic level to another and that matter and energy are conserved as matter cycles and energy flows through ecosystems. Emphasis is on atoms and molecules such as carbon, oxygen, hydrogen and nitrogen being conserved as they move through an ecosystem.
Assessment Boundary	Assessment is limited to proportional reasoning to describe the cycling of matter and flow of energy.
HS-LS4-6. Create or revise a simulation to test a solution to mitigate adverse impacts of human activity on biodiversity.*	
Clarification Statement	Emphasis is on testing solutions for a proposed problem related to threatened or endangered species, or to genetic variation of organisms for multiple species.
HS-LS4-4. Construct an explanation based on evidence for how natural selection leads to adaptation of populations.	
Clarification Statement	Emphasis is on using data to provide evidence for how specific biotic and abiotic differences in ecosystems (such as ranges of seasonal temperature, long-term climate change, acidity, light, geographic barriers, or evolution of other organisms) contribute to a change in gene frequency over time, leading to adaptation of populations.
HS-ESS2-4. Use a model to describe how variations in the flow of energy into and out of Earth's systems result in changes in climate.	
Clarification Statement	Examples of the causes of climate change differ by timescale, over 1–10 years: large volcanic eruption, ocean circulation; 10–100s of years: changes in human activity, ocean circulation, solar output; 10–100s of thousands

	of years: changes to Earth's orbit and the orientation of its axis; and 10–100s of millions of years: long-term changes in atmospheric composition.
Assessment Boundary	Assessment of the results of changes in climate is limited to changes in surface temperatures, precipitation patterns, glacial ice volumes, sea levels, and biosphere distribution.

Instructional Focus

Unit Enduring Understandings (Cross Cutting Concepts)

- **Cause and Effect** Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.
- **Scientific Knowledge Assumes an Order and Consistency in Natural Systems** Scientific knowledge is based on the assumption that natural laws operate today as they did in the past and they will continue to do so in the future.
- **Stability and Change** Much of science deals with constructing explanations of how things change and how they remain stable.
- **Energy and Matter** Energy cannot be created or destroyed—it only moves between one place and another place, between objects and/or fields, or between systems.
- **Systems and System Models** Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions—including energy, matter, and information flows—within and between systems at different scales.

Unit Essential Questions

- How do the biotic and abiotic factors in intertidal, subtidal, estuary, coral reef, and polar communities relate to common adaptations found in these marine environments?
- What are the adaptations of major types of mollusks, echinodermata, arthropods, porifera, cnidarians, cartilage fish, marine reptiles, marine birds, and marine mammals in different marine environments?
- What is the human impact on marine communities? What is the impact that global warming has on marine environments?

Objectives

Students will know (DCIs):

LS1.A: Structure and Function

Multicellular organisms have a hierarchical structural organization, in which any one system is made up of numerous parts and is itself a component of the next level.

LS2.B: Cycles of Matter and Energy Transfer in Ecosystems

Plants or algae form the lowest level of the food web. At each link upward in a food web, only a small fraction of the matter consumed at the lower level is transferred upward, to produce growth and release energy in cellular respiration at the higher level. Given this inefficiency, there are generally fewer organisms at higher levels of a food web. Some matter reacts to release energy for life functions, some matter is stored in newly made structures, and much is discarded. The chemical elements that make up the molecules of organisms pass through food webs and into and out of the atmosphere and soil, and they are combined and recombined in different ways. At each link in an ecosystem, matter and energy are conserved.

LS2.C: Ecosystem Dynamics, Functioning, and Resilience

A complex set of interactions within an ecosystem can keep its numbers and types of organisms relatively constant over long periods of time under stable conditions. If a modest biological or physical disturbance to an ecosystem occurs, it may return to its more or less original status (i.e., the ecosystem is resilient), as opposed to becoming a very different ecosystem. Extreme fluctuations in conditions or the size of any population, however, can challenge the functioning of ecosystems in terms of resources and habitat availability.

LS4.C: Adaptation

Changes in the physical environment, whether naturally occurring or human induced, have thus contributed to the expansion of some species, the emergence of new distinct species as populations diverge under different conditions, and the decline–and sometimes the extinction–of some species.

LS4.D: Biodiversity and Humans

Humans depend on the living world for the resources and other benefits provided by biodiversity. But human activity is also having adverse impacts on biodiversity through overpopulation, overexploitation, habitat destruction, pollution, introduction of invasive species, and climate change. Thus sustaining biodiversity so that ecosystem functioning and productivity are

maintained is essential to supporting and enhancing life on Earth. Sustaining biodiversity also aids humanity by preserving landscapes of recreational or inspirational value.

LS4.C: Adaptation

Natural selection leads to adaptation, that is, to a population dominated by organisms that are anatomically, behaviorally, and physiologically well suited to survive and reproduce in a specific environment. That is, the differential survival and reproduction of organisms in a population that have an advantageous heritable trait leads to an increase in the proportion of individuals in future generations that have the trait and to a decrease in the proportion of individuals that do not.

ESS1.B: Earth and the Solar System

Cyclical changes in the shape of Earth's orbit around the sun, together with changes in the tilt of the planet's axis of rotation, both occurring over hundreds of thousands of years, have altered the intensity and distribution of sunlight falling on the earth. These phenomena cause a cycle of ice ages and other gradual climate changes.

ESS2.A: Earth Materials and Systems

The geological record shows that changes to global and regional climate can be caused by interactions among changes in the sun's energy output or Earth's orbit, tectonic events, ocean circulation, volcanic activity, glaciers, vegetation, and human activities. These changes can occur on a variety of time scales from sudden (e.g., volcanic ash clouds) to intermediate (ice ages) to very long-term tectonic cycles.

ESS2.D: Weather and Climate

The foundation for Earth's global climate systems is the electromagnetic radiation from the sun, as well as its reflection, absorption, storage, and redistribution among the atmosphere, ocean, and land systems, and this energy's re-radiation into space.

Changes in the atmosphere due to human activity have increased carbon dioxide concentrations and thus affect climate.

Students will be able to (SEPs):

- Developing and Using Models
- Using Mathematics and Computational Thinking

UNIT 3: OPEN OCEAN ECOSYSTEMS

Summary and Rationale

This unit includes Photic and Aphotic (Midwater) ecosystems. Students will explore how the biotic and abiotic factors of these communities interact with one another, while discovering the impact humans have on the environment. Students will gain important skills in reading scientific literature, mastering the scientific method, and synthesizing their understanding of complex scientific issues. Students will study many of the organisms in this unique world and will also explore factors and environmental issues that influence and control the abundance and distribution of species in this community.

Recommended Pacing

10 blocks

State Standards

HS-LS1-2. Develop and use a model to illustrate the hierarchical organization of interacting systems that provide specific functions within multicellular organisms.	
Clarification Statement	Emphasis is on functions at the organism system level such as nutrient uptake, water delivery, and organism movement in response to neural stimuli. An example of an interacting system could be an artery depending on the proper function of elastic tissue and smooth muscle to regulate and deliver the proper amount of blood within the circulatory system.
Assessment Boundary	Assessment does not include interactions and functions at the molecular or chemical reaction level.
HS-LS2-4. Use mathematical representations to support claims for the cycling of matter and flow of energy among organisms in an ecosystem.	
Clarification Statement	Emphasis is on using a mathematical model of stored energy in biomass to describe the transfer of energy from one trophic level to another and that matter and energy are conserved as matter cycles and energy flows through ecosystems. Emphasis is on atoms and molecules such as carbon, oxygen, hydrogen and nitrogen being conserved as they move through an ecosystem.
Assessment Boundary	Assessment is limited to proportional reasoning to describe the cycling of matter and flow of energy.
HS-LS4-6. Create or revise a simulation to test a solution to mitigate adverse impacts of human activity on biodiversity.*	
Clarification Statement	Emphasis is on testing solutions for a proposed problem related to threatened or endangered species, or to genetic variation of organisms for multiple species.
HS-LS4-4. Construct an explanation based on evidence for how natural selection leads to adaptation of populations.	
Clarification Statement	Emphasis is on using data to provide evidence for how specific biotic and abiotic differences in ecosystems (such as ranges of seasonal temperature, long-term climate change, acidity, light, geographic barriers, or evolution of other organisms) contribute to a change in gene frequency over time, leading to adaptation of populations.
HS-ESS2-4. Use a model to describe how variations in the flow of energy into and out of Earth's systems result in changes in climate.	
Clarification Statement	Examples of the causes of climate change differ by timescale, over 1–10 years: large volcanic eruption, ocean circulation; 10–100s of years: changes in human activity, ocean circulation, solar output; 10–100s of thousands of years: changes to Earth's orbit and the orientation of its axis; and 10–100s of millions of years: long-term changes in atmospheric composition.
Assessment Boundary	Assessment of the results of changes in climate is limited to changes in surface temperatures, precipitation patterns, glacial ice volumes, sea levels, and biosphere distribution.

Instructional Focus

Unit Enduring Understandings (Cross Cutting Concepts)

- **Cause and Effect** Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.
- **Scientific Knowledge Assumes an Order and Consistency in Natural Systems** Scientific knowledge is based on the assumption that natural laws operate today as they did in the past and they will continue to do so in the future.
- **Stability and Change** Much of science deals with constructing explanations of how things change and how they remain stable.
- **Energy and Matter** Energy cannot be created or destroyed—it only moves between one place and another place, between objects and/or fields, or between systems.
- **Systems and System Models** Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions—including energy, matter, and information flows—within and between systems at different scales.

Unit Essential Questions

- How do the biotic and abiotic factors of open ocean photic and aphotic zones relate to common adaptations found in these marine environments?
- What are the adaptations of major types of plankton and bony fish in different marine environments
- How does light attenuation affect marine organism adaptations?
- What is the impact of oil spills and drilling on marine environments?

Objectives

Students will know (DCIs):

LS1.A: Structure and Function

Multicellular organisms have a hierarchical structural organization, in which any one system is made up of numerous parts and is itself a component of the next level.

LS2.B: Cycles of Matter and Energy Transfer in Ecosystems

Plants or algae form the lowest level of the food web. At each link upward in a food web, only a small fraction of the matter consumed at the lower level is transferred upward, to produce growth and release energy in cellular respiration at the higher level. Given this inefficiency, there are generally fewer organisms at higher levels of a food web. Some matter reacts to release energy for life functions, some matter is stored in newly made structures, and much is discarded. The chemical elements that make up the molecules of organisms pass through food webs and into and out of the atmosphere and soil, and they are combined and recombined in different ways. At each link in an ecosystem, matter and energy are conserved.

LS2.C: Ecosystem Dynamics, Functioning, and Resilience

A complex set of interactions within an ecosystem can keep its numbers and types of organisms relatively constant over long periods of time under stable conditions. If a modest biological or physical disturbance to an ecosystem occurs, it may return to its more or less original status (i.e., the ecosystem is resilient), as opposed to becoming a very different ecosystem. Extreme fluctuations in conditions or the size of any population, however, can challenge the functioning of ecosystems in terms of resources and habitat availability.

LS4.C: Adaptation

Changes in the physical environment, whether naturally occurring or human induced, have thus contributed to the expansion of some species, the emergence of new distinct species as populations diverge under different conditions, and the decline–and sometimes the extinction–of some species.

LS4.D: Biodiversity and Humans

Humans depend on the living world for the resources and other benefits provided by biodiversity. But human activity is also having adverse impacts on biodiversity through overpopulation, overexploitation, habitat destruction, pollution, introduction of invasive species, and climate change. Thus sustaining biodiversity so that ecosystem functioning and productivity are maintained is essential to supporting and enhancing life on Earth. Sustaining biodiversity also aids humanity by preserving landscapes of recreational or inspirational value.

LS4.C: Adaptation

Natural selection leads to adaptation, that is, to a population dominated by organisms that are anatomically, behaviorally, and physiologically well suited to survive and reproduce in a specific environment. That is, the differential survival and

reproduction of organisms in a population that have an advantageous heritable trait leads to an increase in the proportion of individuals in future generations that have the trait and to a decrease in the proportion of individuals that do not.

ESS1.B: Earth and the Solar System

Cyclical changes in the shape of Earth's orbit around the sun, together with changes in the tilt of the planet's axis of rotation, both occurring over hundreds of thousands of years, have altered the intensity and distribution of sunlight falling on the earth. These phenomena cause a cycle of ice ages and other gradual climate changes.

ESS2.A: Earth Materials and Systems

The geological record shows that changes to global and regional climate can be caused by interactions among changes in the sun's energy output or Earth's orbit, tectonic events, ocean circulation, volcanic activity, glaciers, vegetation, and human activities. These changes can occur on a variety of time scales from sudden (e.g., volcanic ash clouds) to intermediate (ice ages) to very long-term tectonic cycles.

ESS2.D: Weather and Climate

The foundation for Earth's global climate systems is the electromagnetic radiation from the sun, as well as its reflection, absorption, storage, and redistribution among the atmosphere, ocean, and land systems, and this energy's re-radiation into space.

Changes in the atmosphere due to human activity have increased carbon dioxide concentrations and thus affect climate.

Students will be able to (SEPs):

- Developing and Using Models
- Using Mathematics and Computational Thinking
- Constructing Explanations and Designing Solutions

UNIT 4: DEEP SEA BENTHIC ECOSYSTEMS

Summary and Rationale

This unit includes Deep Sea Floor & Hydrothermal Vent ecosystems. Students will explore how the biotic and abiotic factors of these communities interact with one another, while discovering the impact humans have on the environment. Students will gain important skills in reading scientific literature, mastering the scientific method, and synthesizing their understanding of complex scientific issues. Students will study many of the organisms in this unique world and will also explore factors and environmental issues that influence and control the abundance and distribution of species in this community.

Recommended Pacing

10 blocks

State Standards

HS-LS1-2. Develop and use a model to illustrate the hierarchical organization of interacting systems that provide specific functions within multicellular organisms.	
Clarification Statement	Emphasis is on functions at the organism system level such as nutrient uptake, water delivery, and organism movement in response to neural stimuli. An example of an interacting system could be an artery depending on the proper function of elastic tissue and smooth muscle to regulate and deliver the proper amount of blood within the circulatory system.
Assessment Boundary	Assessment does not include interactions and functions at the molecular or chemical reaction level.
HS-LS2-4. Use mathematical representations to support claims for the cycling of matter and flow of energy among organisms in an ecosystem.	
Clarification Statement	Emphasis is on using a mathematical model of stored energy in biomass to describe the transfer of energy from one trophic level to another and that matter and energy are conserved as matter cycles and energy flows through ecosystems. Emphasis is on atoms and molecules such as carbon, oxygen, hydrogen and nitrogen being conserved as they move through an ecosystem.
Assessment Boundary	Assessment is limited to proportional reasoning to describe the cycling of matter and flow of energy.
HS-LS4-6. Create or revise a simulation to test a solution to mitigate adverse impacts of human activity on biodiversity.*	
Clarification Statement	Emphasis is on testing solutions for a proposed problem related to threatened or endangered species, or to genetic variation of organisms for multiple species.
HS-LS4-4. Construct an explanation based on evidence for how natural selection leads to adaptation of populations.	
Clarification Statement	Emphasis is on using data to provide evidence for how specific biotic and abiotic differences in ecosystems (such as ranges of seasonal temperature, long-term climate change, acidity, light, geographic barriers, or evolution of other organisms) contribute to a change in gene frequency over time, leading to adaptation of populations.
HS-ESS2-4. Use a model to describe how variations in the flow of energy into and out of Earth's systems result in changes in climate.	
Clarification Statement	Examples of the causes of climate change differ by timescale, over 1–10 years: large volcanic eruption, ocean circulation; 10–100s of years: changes in human activity, ocean circulation, solar output; 10–100s of thousands of years: changes to Earth's orbit and the orientation of its axis; and 10–100s of millions of years: long-term changes in atmospheric composition.
Assessment Boundary	Assessment of the results of changes in climate is limited to changes in surface temperatures, precipitation patterns, glacial ice volumes, sea levels, and biosphere distribution.

Instructional Focus

Unit Enduring Understandings (Cross Cutting Concepts)

- **Cause and Effect** Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.
- **Scientific Knowledge Assumes an Order and Consistency in Natural Systems** Scientific knowledge is based on the assumption that natural laws operate today as they did in the past and they will continue to do so in the future.
- **Stability and Change** Much of science deals with constructing explanations of how things change and how they remain stable.
- **Energy and Matter** Energy cannot be created or destroyed—it only moves between one place and another place, between objects and/or fields, or between systems.
- **Systems and System Models** Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions—including energy, matter, and information flows—within and between systems at different scales.

Unit Essential Questions

- How do the biotic and abiotic factors of benthic deep sea and hydrothermal environments relate to common adaptations found in these marine environments?
- What are the adaptations of major types of agnatha and annelida in different marine environments?
- Why is there controversy surrounding mining and hydrothermal vents?
- What can the history of deep sea exploration tell us?

Objectives

Students will know (DCIs):

LS1.A: Structure and Function

Multicellular organisms have a hierarchical structural organization, in which any one system is made up of numerous parts and is itself a component of the next level.

LS2.B: Cycles of Matter and Energy Transfer in Ecosystems

Plants or algae form the lowest level of the food web. At each link upward in a food web, only a small fraction of the matter consumed at the lower level is transferred upward, to produce growth and release energy in cellular respiration at the higher level. Given this inefficiency, there are generally fewer organisms at higher levels of a food web. Some matter reacts to release energy for life functions, some matter is stored in newly made structures, and much is discarded. The chemical elements that make up the molecules of organisms pass through food webs and into and out of the atmosphere and soil, and they are combined and recombined in different ways. At each link in an ecosystem, matter and energy are conserved.

LS2.C: Ecosystem Dynamics, Functioning, and Resilience

A complex set of interactions within an ecosystem can keep its numbers and types of organisms relatively constant over long periods of time under stable conditions. If a modest biological or physical disturbance to an ecosystem occurs, it may return to its more or less original status (i.e., the ecosystem is resilient), as opposed to becoming a very different ecosystem. Extreme fluctuations in conditions or the size of any population, however, can challenge the functioning of ecosystems in terms of resources and habitat availability.

LS4.C: Adaptation

Changes in the physical environment, whether naturally occurring or human induced, have thus contributed to the expansion of some species, the emergence of new distinct species as populations diverge under different conditions, and the decline–and sometimes the extinction–of some species.

LS4.D: Biodiversity and Humans

Humans depend on the living world for the resources and other benefits provided by biodiversity. But human activity is also having adverse impacts on biodiversity through overpopulation, overexploitation, habitat destruction, pollution, introduction of invasive species, and climate change. Thus sustaining biodiversity so that ecosystem functioning and productivity are maintained is essential to supporting and enhancing life on Earth. Sustaining biodiversity also aids humanity by preserving landscapes of recreational or inspirational value.

LS4.C: Adaptation

Natural selection leads to adaptation, that is, to a population dominated by organisms that are anatomically, behaviorally, and physiologically well suited to survive and reproduce in a specific environment. That is, the differential survival and

reproduction of organisms in a population that have an advantageous heritable trait leads to an increase in the proportion of individuals in future generations that have the trait and to a decrease in the proportion of individuals that do not.

ESS1.B: Earth and the Solar System

Cyclical changes in the shape of Earth's orbit around the sun, together with changes in the tilt of the planet's axis of rotation, both occurring over hundreds of thousands of years, have altered the intensity and distribution of sunlight falling on the earth. These phenomena cause a cycle of ice ages and other gradual climate changes.

ESS2.A: Earth Materials and Systems

The geological record shows that changes to global and regional climate can be caused by interactions among changes in the sun's energy output or Earth's orbit, tectonic events, ocean circulation, volcanic activity, glaciers, vegetation, and human activities. These changes can occur on a variety of time scales from sudden (e.g., volcanic ash clouds) to intermediate (ice ages) to very long-term tectonic cycles.

ESS2.D: Weather and Climate

The foundation for Earth's global climate systems is the electromagnetic radiation from the sun, as well as its reflection, absorption, storage, and redistribution among the atmosphere, ocean, and land systems, and this energy's re-radiation into space.

Changes in the atmosphere due to human activity have increased carbon dioxide concentrations and thus affect climate.

Students will be able to (SEPs):

- Developing and Using Models
- Using Mathematics and Computational Thinking
- Constructing Explanations and Designing Solutions
- Scientific Knowledge is Based on Empirical Evidence