Principle 3: Grades 9-12

Weather and Climate

- Global climate and weather are determined by energy transfer from the sun, energy transfer from the earth to the atmosphere, and interactions between the atmosphere and the earth. These interactions are influenced by factors such as land cover, latitude, altitude, and human activities.

- The ocean absorbs most of the solar radiation reaching the earth. This absorption of radiant energy by the oceans is a major contributor to the earth's climate system.

- Ocean currents influence weather and climate by altering the distribution of heat and moisture around the globe.

- The exchange between the sea and the atmosphere involves a complex system of processes, including evaporation, condensation, precipitation, and the formation of cloud systems.

- Earth's atmosphere is a dynamic system that responds to changes in temperature, pressure, and moisture. These changes influence weather patterns and climate conditions.

- The interaction of ocean and atmosphere produces weather and climate by modifying Earth's energy system.

Principle 3: Grades 9-12

- The ocean has a major influence on weather and climate.

- The oceans are a major influence on global climate by affecting the earth's energy system.

- Changes in the ocean-atmosphere system can affect climate, as changes occur in ocean currents, winds, and atmospheric pressure.

- Increased carbon dioxide levels in the atmosphere can lead to ocean acidification, which affects marine life and ecosystems.

- Climate change may alter ocean currents, wind patterns, and weather conditions, leading to changes in weather and climate.

- As the climate warms, the sea ice melts, affecting the ocean circulation, which in turn affects weather and climate.

- Increased carbon dioxide levels can lead to ocean acidification, which affects marine life and ecosystems.

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**Principle 4:**
**Grades 9-12**

**Oxygen Production**

**A.** The accumulation of oxygen in Earth's atmosphere through photosynthesis was necessary for life to develop and be sustained on land.

**A.1.** All oxygen gas came originally from photosynthetic organisms in the ocean.

**A.2.** About 3 billion years ago, cyanobacteria, with the ability to use sunlight, water, and gases to synthesize organic molecules, produced oxygen gas as a waste product.

**A.3.** Until about 2.5 billion years ago, the majority of oxygen gas produced through photosynthesis was consumed in the process of oxidizing reduced compounds, forming vast sedimentary deposits, and changing the chemistry of the ocean and sediments.

**A.4.** Dissolved oxygen started to accumulate in the ocean when much of the free reduced compounds were oxidized.

**A.5.** The accumulation of oxygen in the ocean allowed for the development of aerobic bacteria that used oxygen in a new biochemical pathway, producing ATP more efficiently.

**A.6.** This energy efficient biochemical pathway that developed in aerobic bacteria, along with oxygen in the ocean, allowed for the development of complex oceanic eukaryotic cells about 2 billion years ago.

**A.7.** Between 2.3 and 2.4 billion years ago, the oxygen concentration in the ocean was high enough that it started to escape and accumulate in the atmosphere, where it formed ozone, blocking much of the UV radiation from reaching the Earth's surface.

**A.8.** Multicellular life, which requires high oxygen levels, developed about 1 billion years ago. By 550 million years ago, free oxygen and ozone levels were high enough to allow the development of terrestrial organisms.

**See Principle 5: C12**

**Principle 4:**
**The ocean makes Earth habitable.**

**B.** Life started in the ocean and the earliest evidence of life is found in ancient ocean sediments.

**B.1.** The millions of different species of organisms on Earth today are related by descent from common ancestors that evolved in the ocean and continue to evolve today.

**B.2.** The fossil record of ancient lifeforms provides evidence for the theory of evolution and the important role the ocean played in the evolution of life on Earth.

**B.3.** The first multicellular organisms to invade land from the ocean were plants, followed by arthropods. Later, organisms, such as lobe-finned fishes, started moving between the shallows and the land. These fishes evolved into amphibians.

**B.4.** One dominant theory about the evolution of early lifeforms (prokaryotes) is that they evolved about 3.5 billion years ago near a hydrothermal vent in the ocean.

**B.5.** Most living organisms, including all animals, plants, fungi, and protists, are eukaryotes that evolved from prokaryotes.

**See Principle 6: A3**
**Principle 5:**
The ocean supports a great diversity of life and ecosystems.

**Diversity of Life**
- The ocean provides a vast, interconnected living space with diverse and unique ecosystems from the surface through the water column and down to the sea floor.

**Diversity of Feeding Behaviors**
- Marine organisms have adaptations for feeding, capturing prey, and avoiding predators.
- Some marine organisms have strategies and structures for finding food in the vast ocean where there is limited abundance of food in specific locations like in coastal regions and upwelling zones, or for foraging for food in large quantities like the open ocean and deep sea.

**Organisms in the ocean have a variety of reproductive strategies and life cycles.**
- Marine organisms have a range of life cycles and reproductive modes from simple, asexual reproduction to complex sexual reproduction, and some species exhibit a mix of asexual and sexual (alternation of generations).
- Marine organisms have strategies for finding mates and maximizing fertilization of eggs in the vast ocean.

**Reproductive strategies of marine organisms lead to variation in population density of the species, and these are connected to mate competition and chance of finding mates.**
- Some examples of these changes between strategies include: benthic adult crabs in the intertidal with a juvenile (larval) larval form, and sessile small crabs with a planktonic larval form.
- Some marine organisms have a hermaphroditic generation, switching between sexual and asexual reproduction each generation (e.g., polyp, stolon). Similar species exhibit various subtypes of evolution through meiosis, and all species develop gametes in preparation for environmental conditions (e.g., marine, aquatic).

**Behavioral strategies include:**
- These strategies include: releasing millions of eggs and sperm into the water (broadcast spawning), which offers no parental care, but increases probability for survival and dispersal of offspring; or producing small batches of fertilized eggs, which offers some parental care (e.g., seahorses, sardines, and pelagic species that have external fertilization, females and males make sperm and eggs (e.g., sea urchins, echinoderms), and for deep-sea and pelagic species, producing fluorescent signals to attract mates (e.g., some pelagic cephalopods).

**For exploiting patchy distribution of food, some strategies include:**
- Migrating long distances (e.g., blue whales, humpback whales, and baleen), and having fat reserves (e.g., marine mammals and sea birds). For surviving in environments where prey are hard to find, some strategies include: having large stomachs and mouths (e.g., deep-sea fish and porpoise) to take advantage of prey when they find it, and hydrodynamic tuned that chase down prey at high speeds.

**Some marine organisms have strategies and structures for capturing food in a watery environment where food may be suspended in the water column; the organism has to encounter the fluid motion of water and buoyancy.**
- Some marine organisms have symbiotic relationships that help them acquire energy.

**Diversity of Life Cycles and Reproductive Strategies**
- Marine organisms have different lifecycles (e.g., planktonic, nektic, benthic), and many transition between stages as part of their life cycle, which allow them to survive in different ecosystems at different stages in their development. This is advantageous for a variety of reasons, such as juveniles accessing different resources (e.g., food and space), limiting competition, and facilitating reproduction at different stages. Marine organisms also have decreased predation rates and increased availability of nutrients for juveniles.

**These strategies include:**
- Using multiple environmental cues, such as day length, tidal cycles, seasonal variations, and patterns in current patterns to synchronize their breeding (e.g., herring) or spawning (e.g., salmon), and for deep-sea and pelagic species, producing fluorescent signals to attract mates (e.g., some pelagic cephalopods). These strategies include: releasing millions of eggs and sperm into the water.