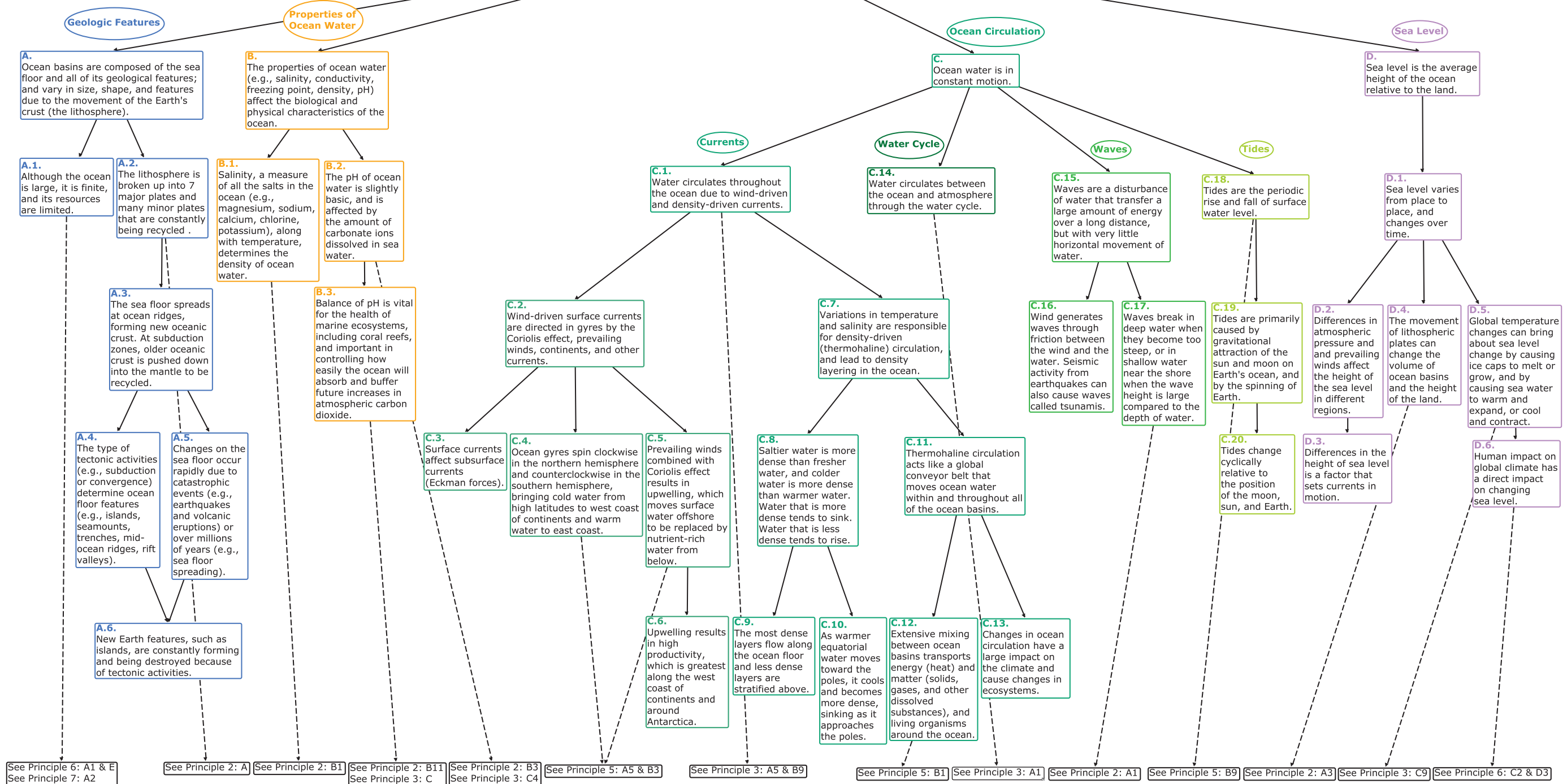


PRINCIPLE 1: GRADES 9-12

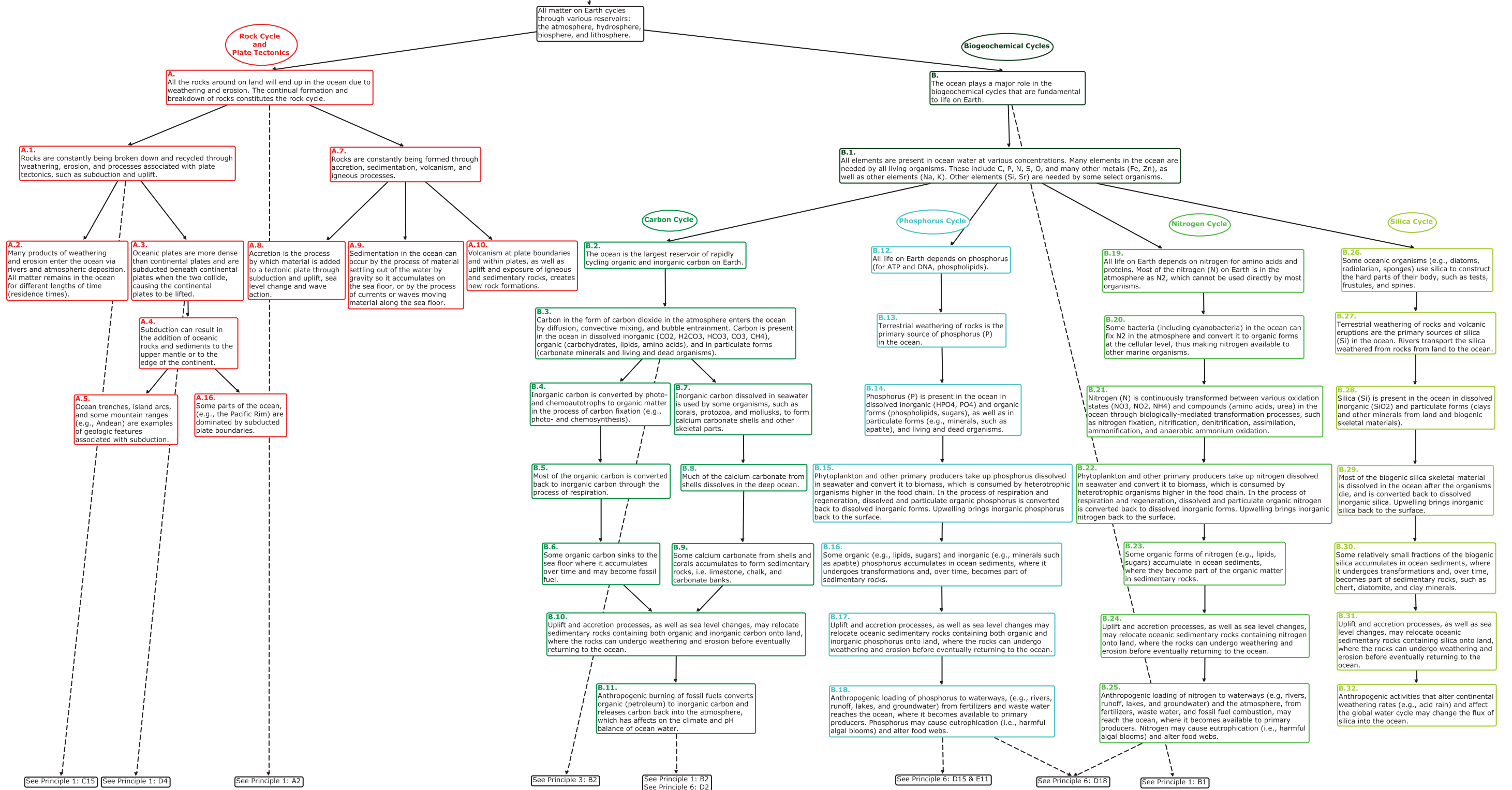
Principle 1: The Earth has one big ocean with many features.

The ocean, which covers 70% of Earth's surface, is the defining feature of the planet.



PRINCIPLE 2: GRADES 9-12

Principle 2: The ocean and life in the ocean shape the features of the Earth.



PRINCIPLE 3: GRADES 9-12

Principle 3: The ocean has a major influence on weather and climate.

The interaction of oceanic and atmospheric processes control weather and climate by dominating Earth's energy system.

Weather and Climate

A. Global climate and weather are determined by energy transfer from the sun. Energy transfer from the sun is influenced by the ocean, the topography of the land, by processes such as cloud cover and Earth's rotation, and other factors.

A.1. The ocean absorbs most of the solar radiation reaching Earth. Differential heating of Earth results in circulation patterns in the atmosphere and ocean that globally distribute the heat.

A.2. The ocean's absorption of heat moderates the global climate.

A.5. Heat exchange between the ocean and the atmosphere drives oceanic and atmospheric circulation and the water cycle.

A.16. Seasonal and short-term changes in ocean temperature can affect rainfall and temperatures on land (i.e. weather). Long-term changes in ocean temperature can affect the climate.

A.3. The weather along coastlines is generally more moderate than inland regions due to the greater heat capacity of the ocean.

A.4. Ocean currents move heat throughout the ocean basins.

A.6. Heating of Earth's surface and atmosphere by the sun drives circulation of the upper layers of the ocean.

A.8. Heat exchange between the ocean and atmosphere can result in dramatic global and regional weather phenomena, including impacting patterns of rain and drought.

A.13. Heat stored in the tropical ocean provides energy for weather, including hurricanes, cyclones, and polar storms.

A.7. Differential heating causes vertical convection in the atmosphere, which helps drive horizontal wind patterns. Those winds transfer energy to the ocean through surface wind stress, which drives the upper layer circulation patterns of the ocean.

A.9. El Niño Southern Oscillation (ENSO) and La Niña events are significant examples of global ocean/atmosphere phenomena, and cause important changes in global weather patterns because they alter the sea surface temperature patterns in the Pacific.

A.14. Most precipitation that falls on land evaporated from the tropical ocean.

A.10. The increase in sea surface temperature increases atmospheric convection, changing patterns of rainfall and drought.

A.11. El Niño and La Niña events affect ocean ecological communities.

A.12. El Niño and La Niña events can affect terrestrial processes, such as fire frequency, drought, flooding, etc.

See Principle 1: C14

See Principle 1: C1

Principle 6: C

Global Climate Change

B. Changes in the ocean/atmosphere system can result in changes to the climate.

B.1. Carbon-containing gases (e.g., carbon dioxide and methane) are exchanged between the ocean and the atmosphere. These gases are called greenhouse gases. The exchange of carbon is part of the carbon cycle.

B.2. Greenhouse gases in the atmosphere create a greenhouse effect by trapping longwave radiation and preventing it from leaving Earth, thus contributing to the warming of the atmosphere. The ocean removes and stores atmospheric carbon dioxide through biological and chemical activity that mediates the global greenhouse effect.

B.5. The ocean and atmosphere are in a dynamic equilibrium related to carbon fluctuation. Excess carbon input into the atmosphere, including that from human activity, changes this equilibrium.

B.3. Carbon dioxide is taken up by phytoplankton through photosynthesis.

B.4. Ocean absorption of carbon dioxide may produce carbonic acid, which increases the acidity of the ocean.

B.6. An increase in greenhouse gases contributes to excessive warming of the atmosphere.

B.7. A primary source of excess carbon dioxide is burning fossil fuels.

B.8. Deforestation reduces the amount of photosynthesis, increasing the amount of carbon dioxide in the atmosphere.

B.11. Changes in ocean circulation have produced large, abrupt changes in climate during the last 50,000 years.

See Principle 2: B3

See Principle 6: D2

Consequences of Global Climate Change

C. Changes to weather and climate, which result from changes to the ocean/atmosphere system, have physical, chemical, biological, economic, and social consequences.

C.1. Climate change may affect the frequency and intensity of hurricanes and cyclones.

C.2. Climate change may alter the frequency and intensity of El Niño and La Niña events.

C.4. Increased carbon dioxide in the atmosphere can lead to ocean acidification.

C.6. Climate change affects species distribution, productivity, and diversity in the ocean.

C.8. As the climate warms, the rate at which glaciers and ice caps melt increases.

C.3. More frequent and/or intense El Niño and La Niña events may have worldwide economic impacts, e.g., collapse of fisheries, decreased agricultural production, etc.

C.5. Ocean acidification may alter biological activity, including inhibiting the ability of organisms to form shells, bones and exoskeletons, and may also dissolve these structures.

C.7. Climate change is changing ocean temperature, which can result in ecosystem changes, such as coral bleaching and redistributions of commercially valuable species.

C.9. As glaciers and ice caps melt, sea level rises. Rising sea level can inundate coastal regions and low-lying islands, destroying habitats and submerging ecosystems and human communities.

C.10. Ice reflects a large amount of heat from the sun back into the atmosphere. When ice melts, less heat is reflected back into the atmosphere, further warming the land and causing more ice to melt.

C.11. An increase in melting ice may cause a decrease in regional salinity. This can change ocean circulation.

See Principle 1: C1

See Principle 1: B2

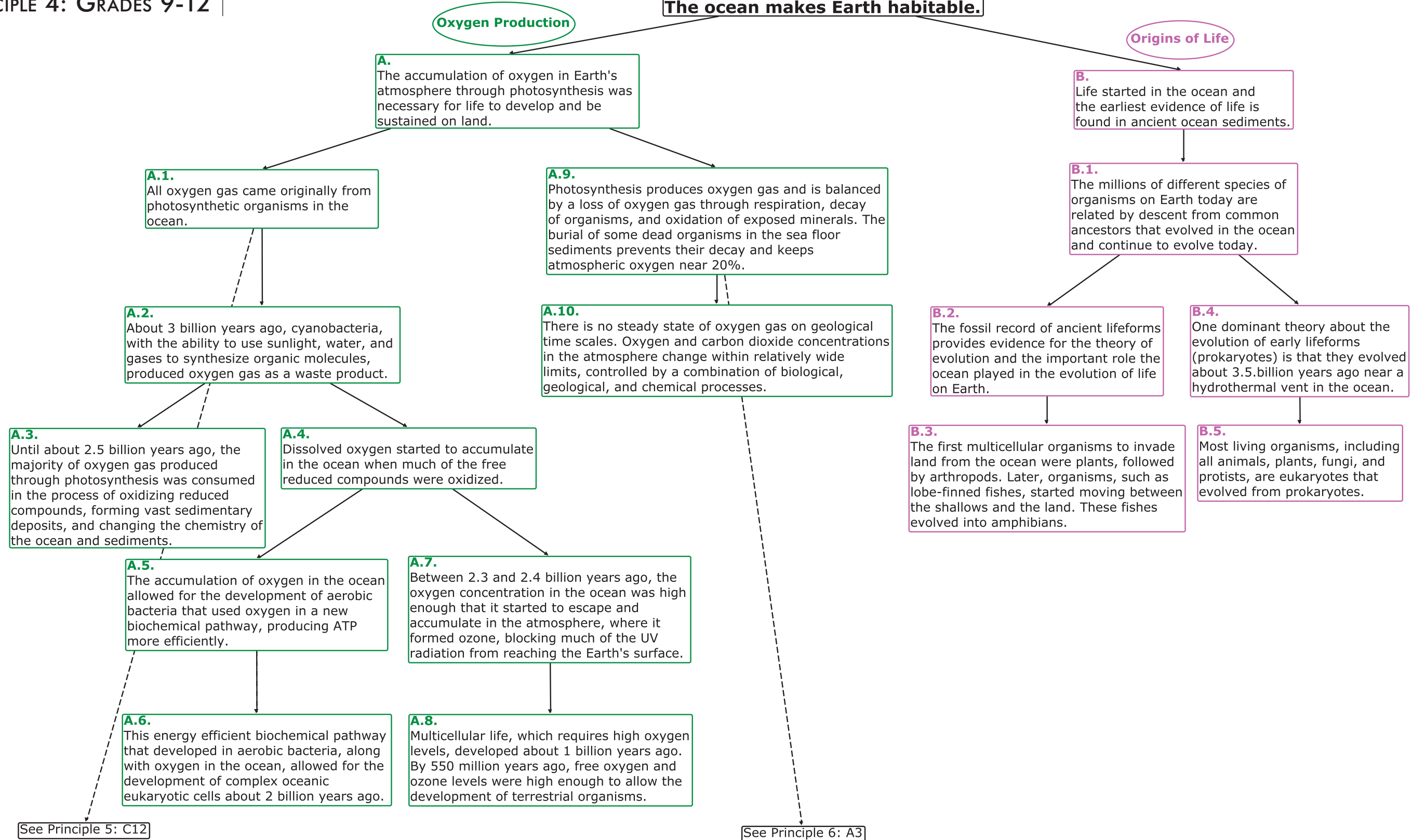
See Principle 5: C35

See Principle 5: C36

See Principle 1: D5

PRINCIPLE 4: GRADES 9-12

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



PRINCIPLE 5: GRADES 9-12*

*PRINCIPLE 5 INCLUDES THREE FLOWS (SEE PAGES 59 AND 60).

Principle 5:
The ocean supports a great diversity of life and ecosystems.

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.

Primary Productivity

Ecosystem Diversity

A.
Microbes, such as cyanobacteria and phytoplankton, are the most abundant lifeforms, and the most important primary producers in the ocean. They are the base of most of the food chains in the ocean.

B.
Ocean ecosystems are defined by environmental factors and the community of organisms living there.

A.1.
Primary production is the net gain in organic matter that occurs when producers make more organic matter than they use in respiration.

A.7.
Chlorophyll, the green pigment found in microbes, algae, and other photosynthetic organisms, absorbs energy from sunlight; and together with carbon dioxide (inorganic carbon) and water, converts and stores chemical energy in the form of glucose (organic carbon).

B.1.
Ocean life is not evenly distributed through time or space due to differences in abiotic factors such as oxygen, salinity, temperature, pH, light, nutrients, pressure, substrate, and circulation. A few regions of the ocean support the most abundant life on Earth, while the vast majority of the ocean does not support much life.

B.7.
Ocean ecosystems are often composed of habitats and microhabitats that exist in distinct, vertically distributed zones. Vertical zonation exists as distinct horizontal layers or bands on the coastline and throughout the water column.

A.2.
Nutrients, such as minerals and vitamins, are needed to convert glucose into other organic material used to grow and reproduce. Some of the most important nutrients for producers in the ocean include: nitrogen (especially nitrate), phosphate, silicate, and iron. Nitrogen is often the nutrient in shortest supply.

A.6.
Organisms that do not make their own food (heterotrophs) are dependent on the primary producers (autotrophs) to get the energy and matter they need to survive.

B.2.
Ocean ecosystems with the greatest abundance of life occur where environmental conditions and/or adaptations allow for high levels of productivity.

B.8.
Zonation patterns occur in part because ocean organisms are adapted to live within specific environmental conditions.

B.11.
Ocean ecosystems are connected to each other in a macro food web. Over time, organisms move from one ecosystem to another as they grow, migrate, and die. Changes in an ecosystem or an organism may have unpredictable effects on other ecosystems.

B.12.
Ocean ecosystems support a large number of niches—the range of environmental conditions, including physical (e.g., temperature, depth) and biological (e.g., competitors, predators) under which an organism can live, and its role in the ecosystem (e.g., what it does and what it eats).

A.3.
Most of the nutrients needed for primary productivity come from nutrient recycling. Nitrogen, phosphorous, and other nutrients in organic molecules, such as proteins and nucleic acids, are released when organisms die and are decomposed by bacteria.

A.4.
Some of the organic matter produced by primary producers sinks below the sunlit surface zone, carrying nutrients to the deep.

B.3.
Coastal habitats, such as estuaries and kelp forests, support a great diversity and number of organisms, which is due in part to: abundant sunlight and current patterns (e.g., upwelling, which brings nutrients to the surface, and nutrients flowing into the ocean from rivers).

B.4.
There are deep ocean ecosystems that are independent of energy from sunlight and photosynthetic organisms. Hydrothermal vents, submarine hot springs, and methane cold seeps rely only on chemical energy and chemosynthetic organisms to support life.

B.5.
Coral reefs, one of the most diverse ecosystems on Earth, thrive in nutrient-poor, warm waters because of a symbiotic relationship between corals and zooxanthellae, a type of dinoflagellate. This relationship enables corals to grow, forming substrates that are the foundation of complex reef ecosystems.

B.9.
Many intertidal organisms are adapted to survive in zones defined by tidal cycles (amount of time exposed to air), crashing waves, predation, or substrate.

B.10.
Many open ocean organisms are adapted to live only within distinct density layers or in zones defined by pressure or light levels.

B.13.
Niches in the ocean are in a very dynamic environment, contributing to the high diversity seen in this ecosystem, e.g. sudden upwelling events create an environment conducive to the survival of a different set of organisms than were present prior to the influx of nutrient-rich water.

A.5.
There is a direct relationship between primary productivity, current patterns, and upwelling. The highest levels of primary productivity are near the polar regions and in upwelling zones where there are high levels of nutrients and sunshine.

See Principle 2: B1

See Principle 1: C5

See Principle 2: B4

See Principle 1: C12
See Principle 2: B1

See Principle 1: C17

PRINCIPLE 5: GRADES 9-12*

*PRINCIPLE 5 INCLUDES THREE FLOWS (SEE PAGES 58 AND 60).

Principle 5: The ocean supports a great diversity of life and ecosystems.

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 Life

C. The diversity of ocean ecosystems allows for many lifeforms and adaptations of ocean organisms.

Diverse Adaptations to Environmental Factors

C.22. Organisms in the ocean exhibit a wide variety of adaptations to survive in a watery environment.

Phyletic Diversity

C.1. The diversity of phyla is greater in the ocean than on land, and includes a range of organisms, from the smallest living things (microbes) to the largest animal on Earth (blue whales).

C.2. The first forms of life started in the ocean and evolved into the phyla seen today.

C.3. The first vertebrates to evolve were fish. Fish are the most numerous vertebrates in terms of species and individuals.

C.4. Some major groups left the ocean and evolved further on land. Some members of those groups later returned to the ocean, such as mammals, reptiles, birds, and flowering plants.

C.5. The majority of phyla that exist on Earth are still found exclusively in the ocean. These include seaweeds, echinoderms, tunicates, and most sponges and cnidaria. There is only one phylum that exists uniquely on land.

C.6. All major groups of invertebrates have marine representatives, and many only live in marine environments. Except for the insects, most invertebrate species and thus most animals, are marine. At least 97% of all species of animals are invertebrates.

C.7. Seaweeds are eukaryotes, multicellular, photosynthetic organisms that have no seeds, and lack true roots and leaves. There are three phyla of seaweeds: green, brown, and red.

C.10. Some bacteria and archaea are chemosynthetic primary producers, and make their own food from chemical compounds, such as hydrogen sulfide at hydrothermal vents.

C.11. Most marine bacteria are heterotrophs that break down detritus and recycle essential nutrients back into the environment. Some symbiotic bacteria are responsible for the bioluminescence of some deep sea fish and squid.

C.12. Photosynthetic bacteria, called cyanobacteria, are thought to have made most of the oxygen in the atmosphere. Cyanobacteria were the first photosynthetic organisms, and still produce much of Earth's oxygen.

C.14. Dinoflagellates are phytoplankton that have animal-like features, such as flagella, and can ingest food as heterotrophs. Some of these organisms cause red tides and bioluminescence. Some, called zooxanthellae, have symbiotic relationships with organisms such as corals.

C.15. Coastal pollution can cause an increase in the numbers of some dinoflagellates, leading to disease in humans and marine organisms.

C.16. Diatoms are phytoplankton that produce a huge amount of the carbon and oxygen produced on Earth. Diatoms have cell walls made of glass-like silica. The ocean floor is covered by vast deposits of these siliceous sediments.

C.17. Some diatoms are harmful, including those that produce domoic acid, which accumulates in shellfish and fish and may lead to death in mammals that eat them.

C.19. The ocean supports larger animals than on land due to its unique physical and biological characteristics.

C.20. Seawater is denser than air, and thus support animals with much greater mass.

C.18. There are many species of marine fungi and they are mostly microbes. Most of these are decomposers.

C.23. There are varying levels of light in the ocean. Some ocean organisms have adaptations that allow them to stay near the sunlit surface. These adaptations allow some to photosynthesize (e.g., phytoplankton, kelp) and others to stay near their food source (e.g., zooplankton).

C.24. Plankton have features, such as oil droplets, spines, cilia, flagella, and/or a large surface area to volume ratio.

C.25. The ocean acts as a filter, and allows different wavelengths of light to penetrate to different depths: red, yellow, and orange wavelengths are filtered out in shallow water; green and blue light penetrate the deepest. The color of some organisms is a feature that allows them to be camouflaged at different depths.

C.26. Even in relatively shallow water, many red organisms appear gray and are camouflaged.

C.27. Since sound travels through the ocean further and faster than light does, many marine animals, from shrimp to whales, rely on sound to communicate, find prey and mates, and sense their environments.

C.28. Many large whales use low-frequency sound to communicate across entire ocean basins. Many toothed whales use echolocation to find and/or capture prey. Pistol shrimps use blasts of sound to shock prey.

C.29. Some ocean organisms have adaptations for living in or diving to the deep ocean.

C.30. Some marine mammals have many adaptations for deep diving, such as breath holding, slowing their heart rate, reducing blood flow to non-vital organs, and increasing oxygen storage. Many organisms use bioluminescence to find or attract prey and mates, and escape predators.

C.31. Marine organisms have adaptations that allow them to osmoregulate in a saltwater environment.

C.32. The body fluids of many marine organisms, including most fish, are more dilute than the surrounding seawater, so they tend to lose water by osmosis. To compensate, fish drink seawater and excrete salt through their gills and urine. Other organisms change the amount of ions in their body to match the salinity in the environment, (e.g., sharks regulate urea in their blood to match the ocean's salinity).

C.33. Marine organisms are adapted to live within particular ecosystems in a relatively stable ocean where there are only small fluctuations in pH and temperature.

C.34. Small changes in temperature and pH due to human activities can affect an organisms' survival and biological diversity, (e.g., coral bleaching due to increased temperature and inhibition of shell formation due to ocean acidification).

C.35. Shelled organisms use calcium carbonate to construct shells and skeletons, relying on the abundant carbonate ions usually available in ocean water. As ocean pH decreases, the concentration of available carbonate ions also decreases, and carbonate from the shells dissolves into the ocean water, leading to thinning shells.

C.36. Small increases in temperature can lead to coral bleaching as the symbiotic algae (zooxanthellae) living inside the coral polyp leave resulting in the death of the coral.

See Principle 4: A1

See Principle 6: D18

See Principle 3: C4

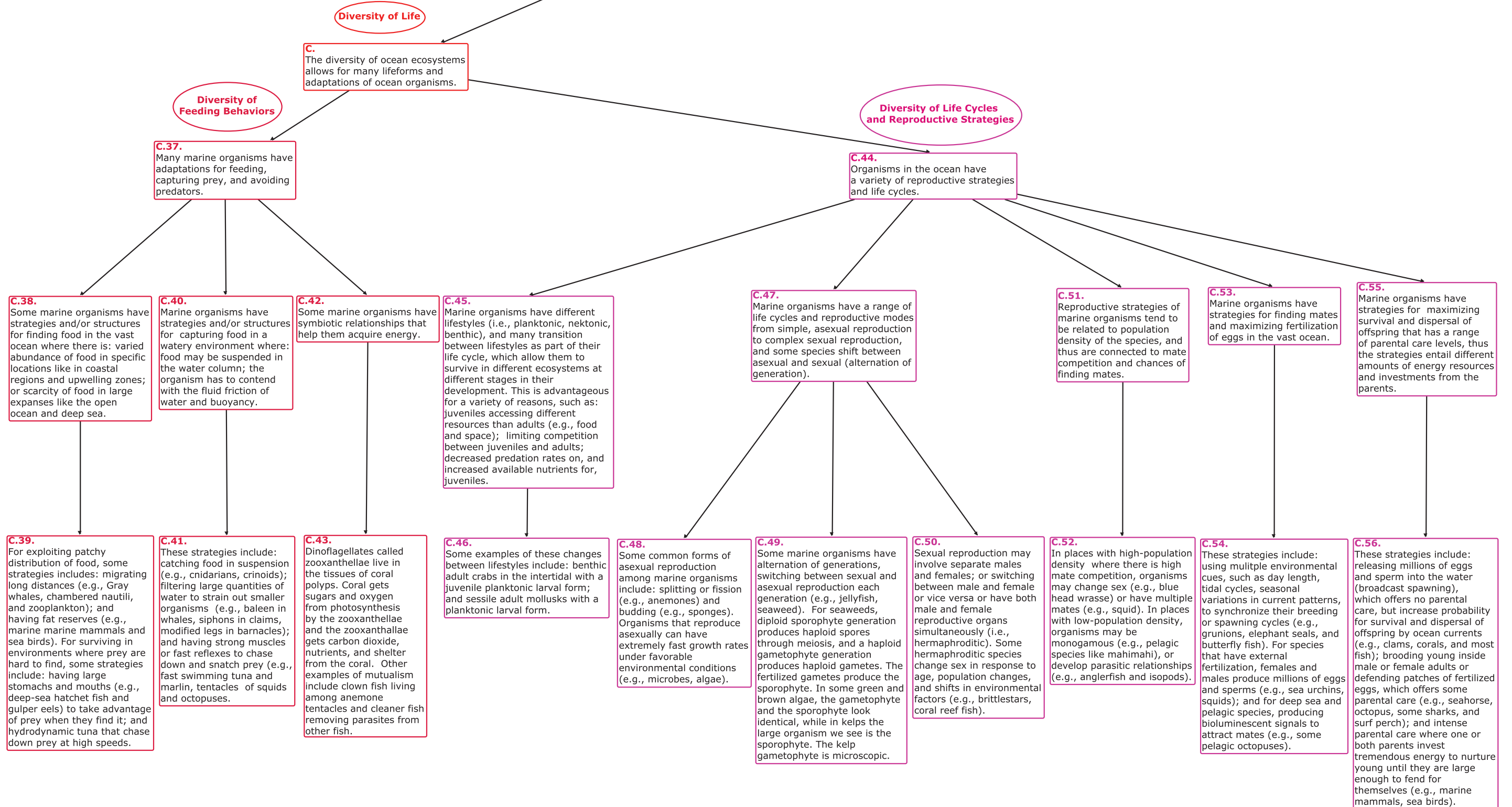
See Principle 6: C36

PRINCIPLE 5: GRADES 9-12*

*PRINCIPLE 5 INCLUDES THREE FLOWS (SEE PAGES 58 AND 59).

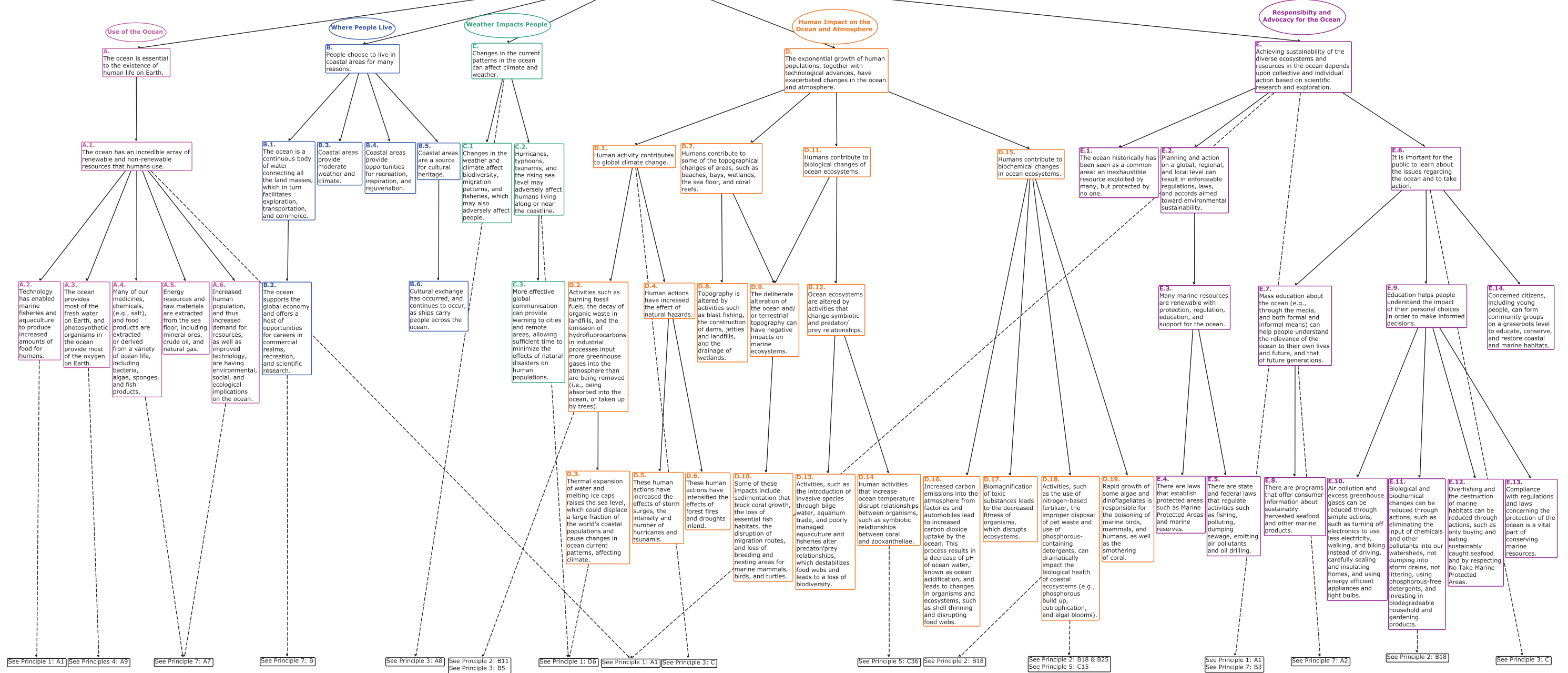
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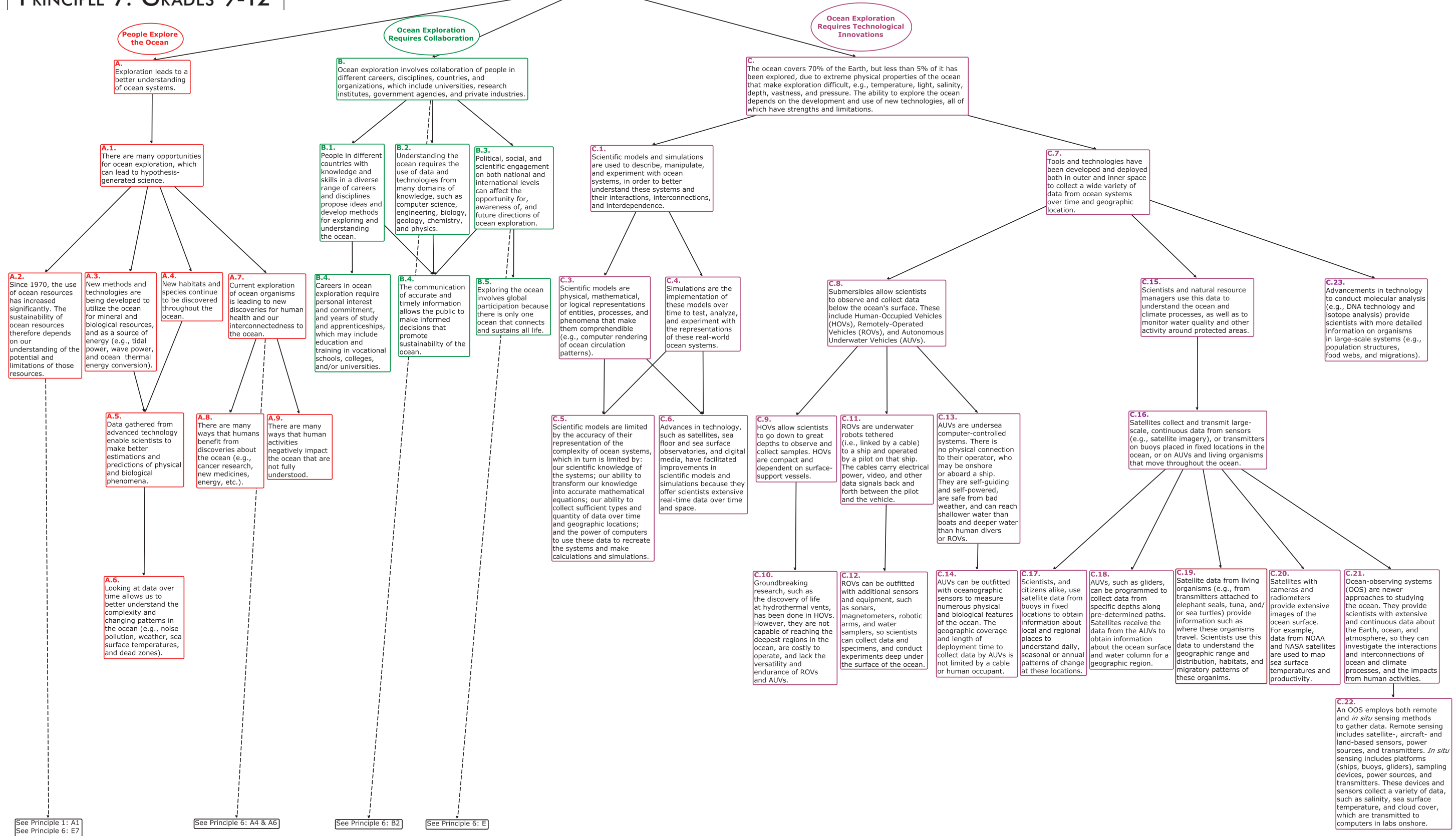
PRINCIPLE 6: GRADES 9-12

Principle 6: The ocean and humans are inextricably interconnected.



PRINCIPLE 7: GRADES 9-12

Principle 7: The ocean is largely unexplored.



See Principle 1: A1
See Principle 6: E7

See Principle 6: A4 & A6

See Principle 6: B2

See Principle 6: E