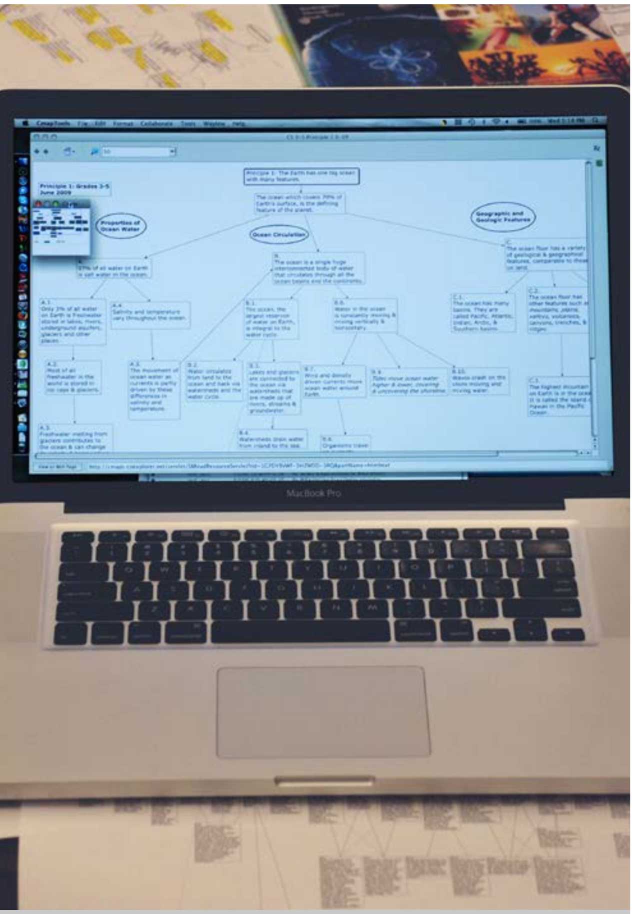


The freeware **CmapTools** was used in developing the conceptual flow diagrams (Photo credit: Craig Strang)

Introduction to the Ocean Literacy Scope and Sequence for Grades K through 12

The Ocean Literacy Scope and Sequence for Grades K–12 is a series of 28 conceptual flow diagrams[3] that represent and organize the ideas of the seven Ocean Literacy Principles into four grade bands—K through 2, 3 through 5, 6 through 8, and 9 through 12—effectively showing what students should know at the end of 2nd, 5th, 8th, and 12th grades. This document provides specific guidance to educators, standards committees, curriculum developers, and scientists conducting outreach. It is one part of the Ocean Literacy Framework which comprises four key documents:

» *Ocean Literacy: The Essential Principles of Ocean Sciences for Learners of All Ages*;

» *The Ocean Literacy Scope and Sequence for Grades K–12*;

» *Alignment of Ocean Literacy to the Next Generation Science Standards*; and

» *International Ocean Literacy Survey*.

The scope and sequence was developed iteratively and thoughtfully with significant and substantive participation by hundreds of scientists, science educators, and classroom teachers around the country.[4] Thus, it represents a community consensus regarding the essential ideas in ocean sciences that all students should understand by the end of Grade 12 and a road map for how to get there.

The scope and sequence conceptual flow diagrams provide specific guidance to help educators as they work to grow their learner's conceptual understanding of essential ocean concepts. Dive into the conceptual flow diagrams on the following pages.

To access online versions of the Framework documents, please visit **www.marine-ed.org/ocean-literacy/overview**

3 See "Developing the Ideas of Ocean Literacy Using Conceptual Flow Diagrams" in this handbook.

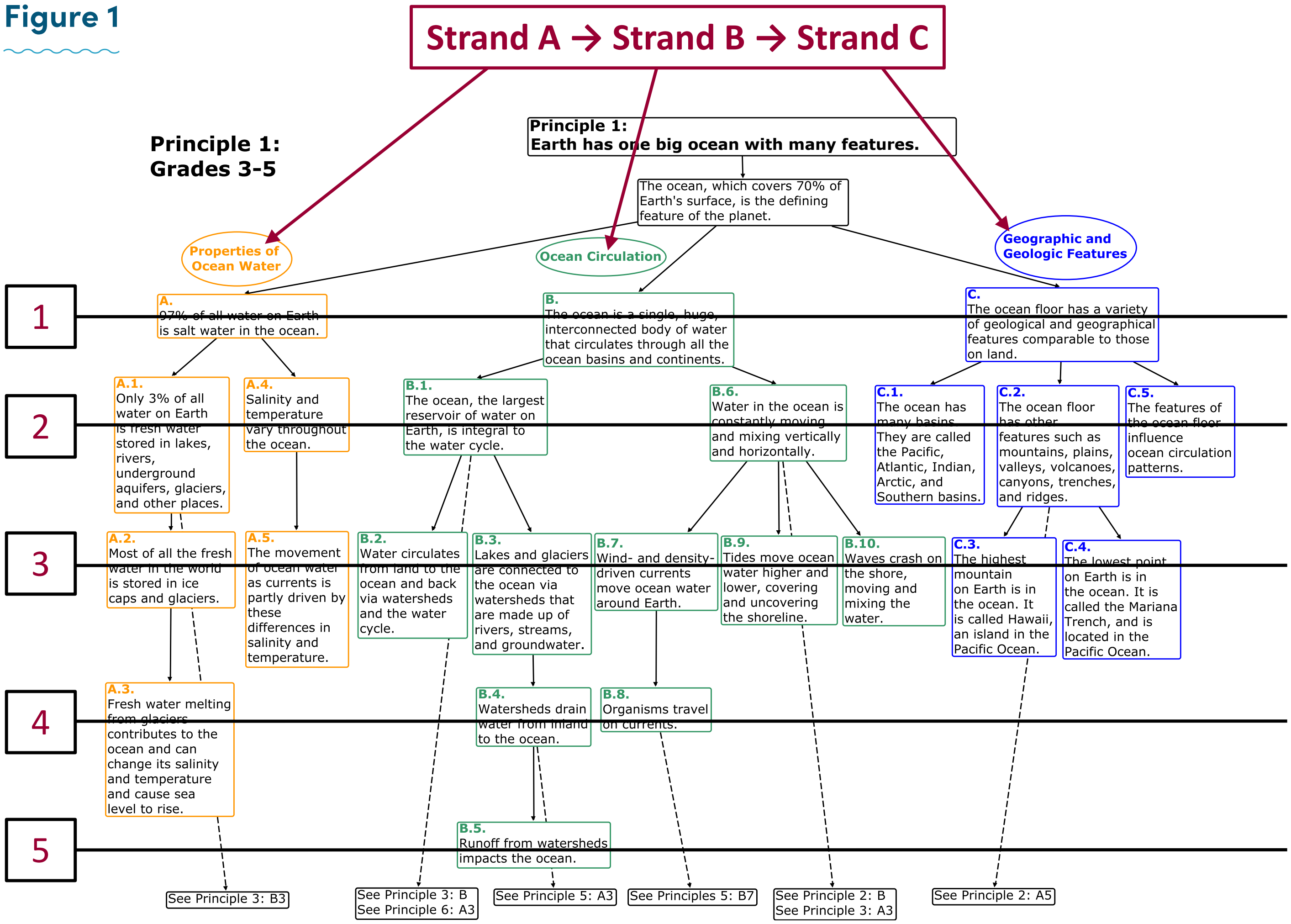
4 A more complete history is provided in the introduction to this handbook.

The Ocean Literacy Scope and Sequence comprises 28 conceptual flow diagrams (hereafter referred to as flows). There is one flow for each principle for each grade band (K through 2, 3 through 5, 6 through 8, and 9 through 12). Each flow is read from top to bottom and left to right and represents one possible way of breaking down and organizing the major concepts and supporting ideas for each principle for a grade band.

The essential principle as well as the grade level are listed at the top of the page. The diagram shows three sets of text boxes (called strands) cascading down the page. Each strand represents a topic related to the essential principle and includes concepts and supporting subconcepts focused on the topic.

Conceptual flow diagrams can be used as a suggested instructional sequence, organizer of ideas, and/or indicator of learning progression.

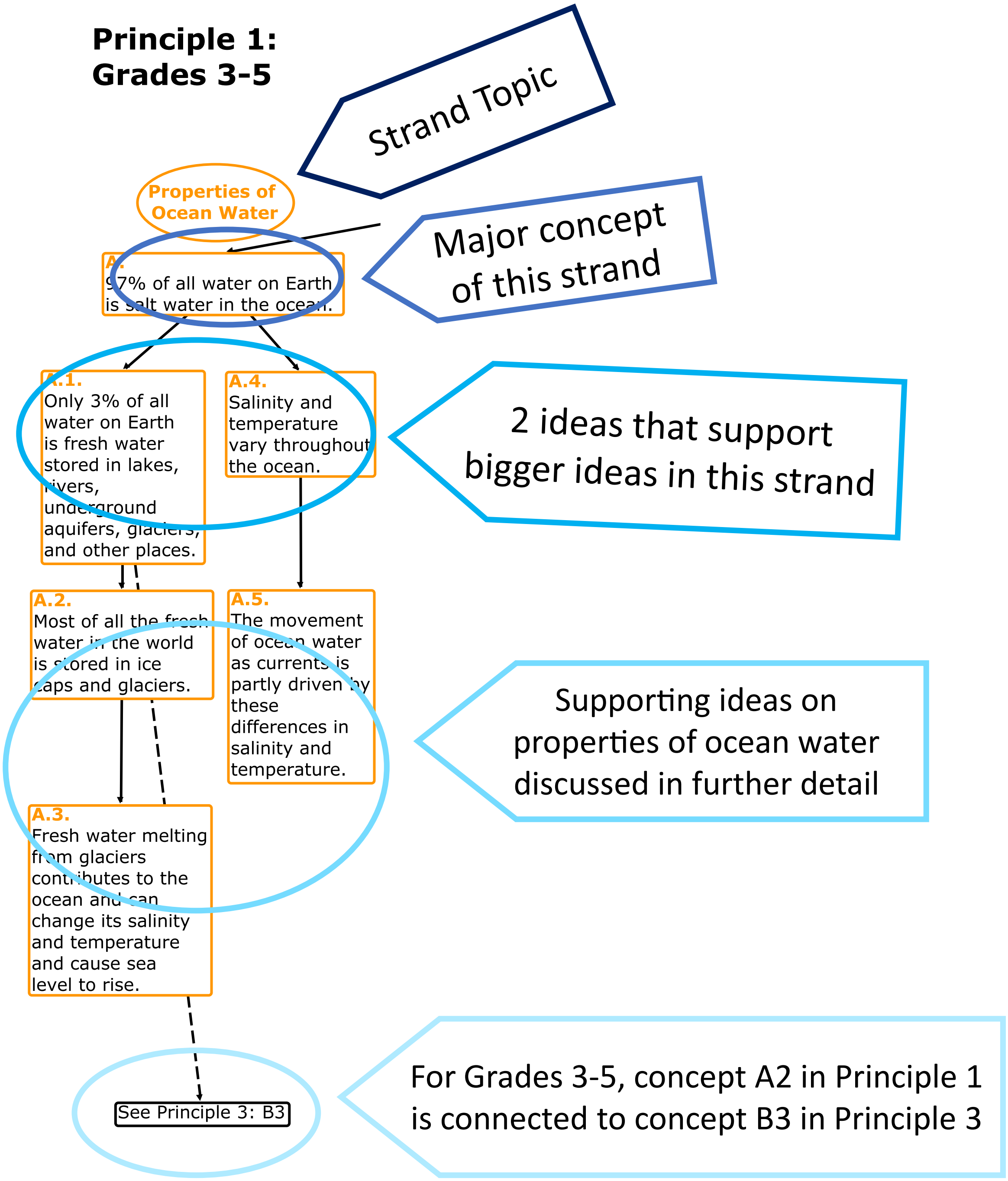
Figure 1



Dashed lines lead to cross-referenced concept statements in other essential principles.

In this flow for Principle 1, Grades 3 through 5, there are three strands of topics and five levels of ideas. Read the flow from top to bottom and left to right, from Strand A (A1 to A5) to Strand B (B1 to B10) to Strand C (C1 to C5). Some of the concepts cross-reference other concepts in other principles within that same grade band. These cross-references are connections between principles.

Figure 2

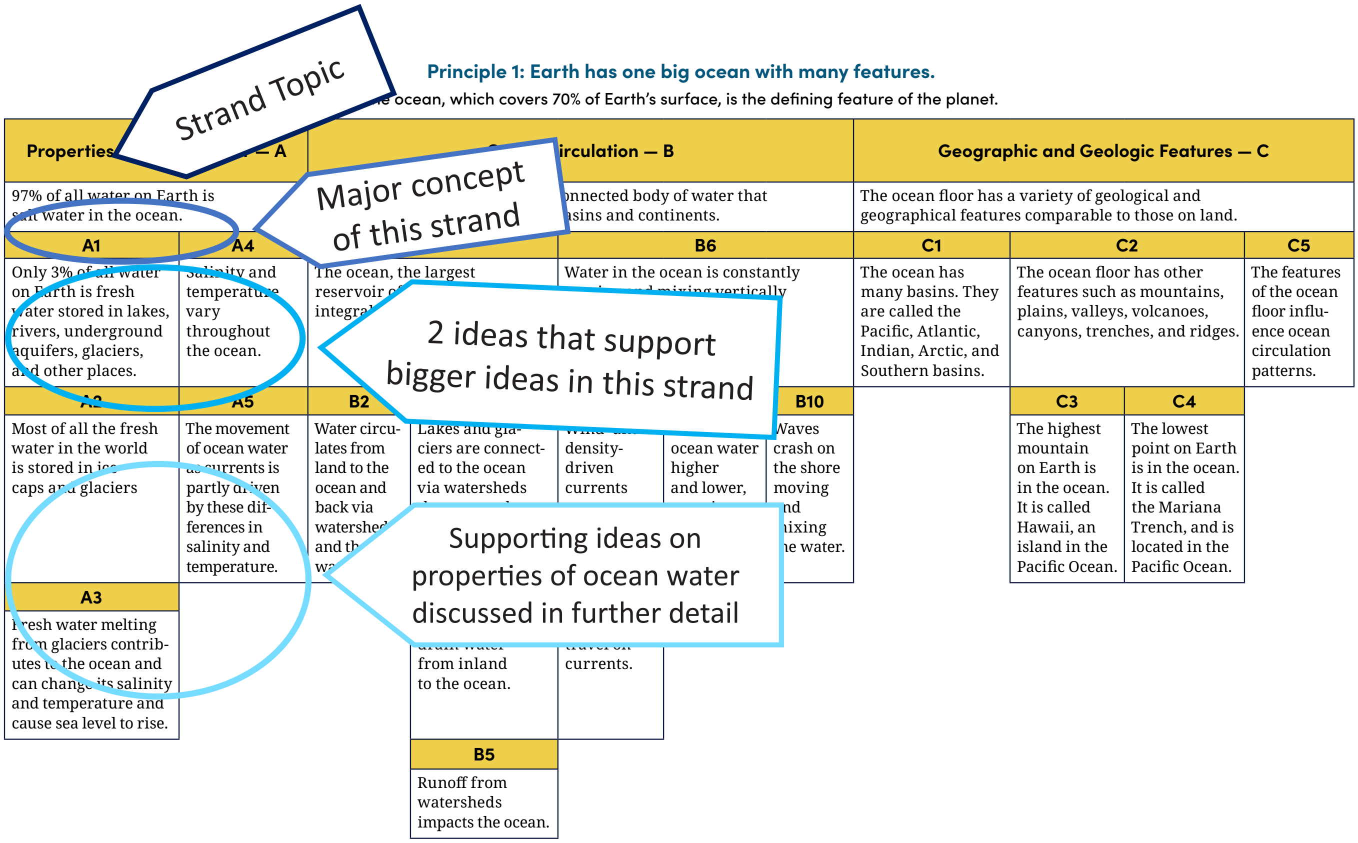


Strand A of conceptual flow diagram of Principle 1 for Grades 3 to 5. Here is a breakdown of the components in a strand. The strand is identified by topic for easy reference. The strand begins with a major concept and then nested below are two levels of ideas that support the bigger idea. Supporting ideas can be examples, but not always.

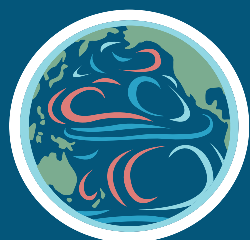
How to Use the Alternative Form of the Conceptual Flow Diagrams

In addition to the conceptual flow diagrams of the *Ocean Literacy Scope and Sequence for Grades K–12*, we also present the concepts in a tabular format. This helps convey the connections and relationships between concepts, without relying on visual cues.

Strands of connected ideas are organized under a topic title and brief description. Instead of using arrows to convey connections between individual concepts, concepts are stacked in columns in the order in which they should be presented (i.e., top to bottom, then left to right). This means some concepts are repeated under each higher level concept to convey the connections among them. As users of assistive technology navigate the tables, the concepts become more and more specific.



Conceptual Flow Diagrams



Principle 1

Principle 2

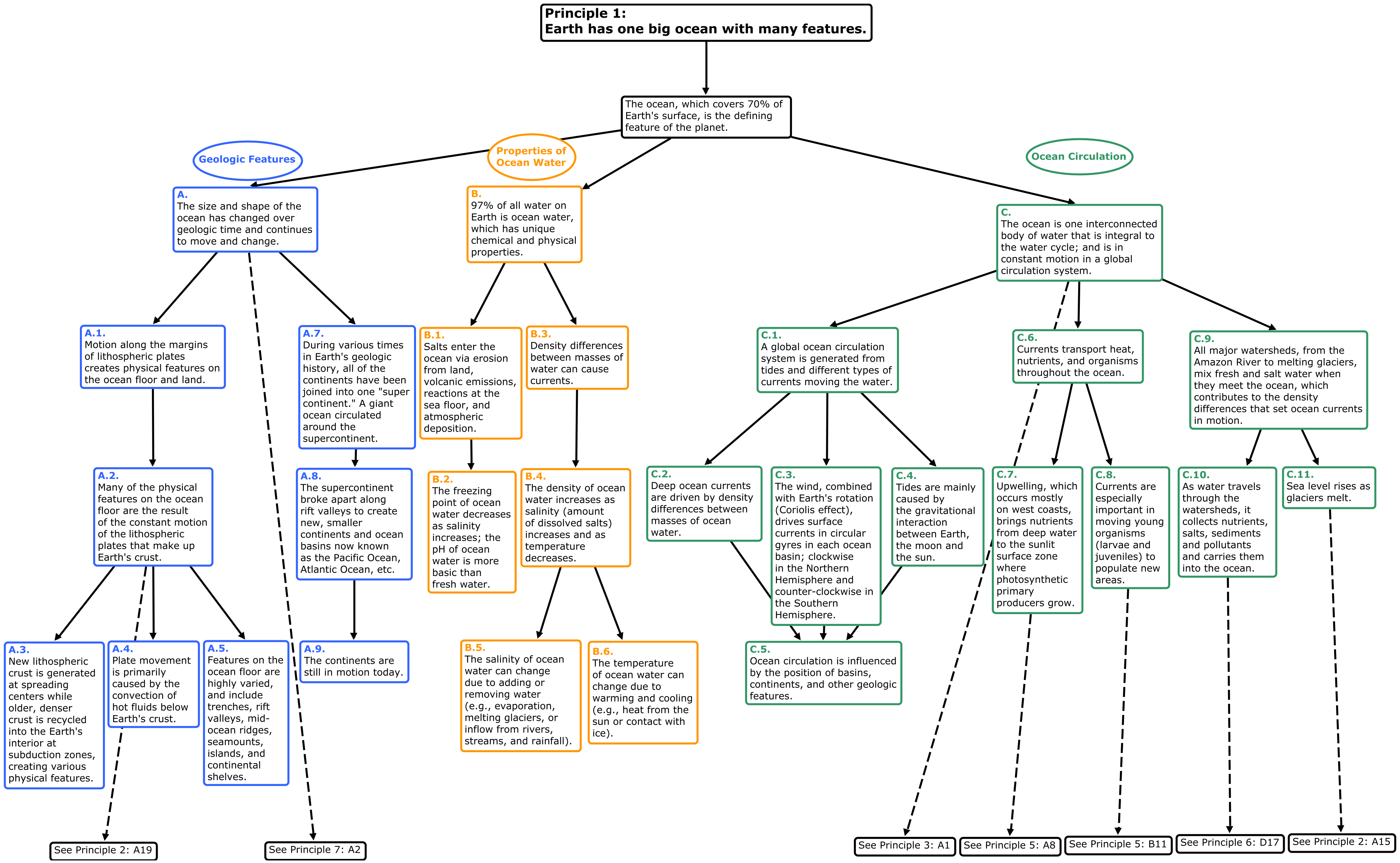
Principle 3

Principle 4

Principle 5

Principle 6

Principle 7


Principle 1:
Earth has one big ocean with many features.
The ocean, which covers 70% of Earth's surface, is the defining feature of the planet.
Geologic Features
Properties of Ocean Water
Ocean Circulation
A. The size and shape of the ocean has changed over geologic time and continues to move and change.
A.1. Motion along the margins of lithospheric plates creates physical features on the ocean floor and land.
A.2. Many of the physical features on the ocean floor are the result of the constant motion of the lithospheric plates that make up Earth's crust.
A.3. New lithospheric crust is generated at spreading centers while older, denser crust is recycled into the Earth's interior at subduction zones, creating various physical features.
A.4. Plate movement is primarily caused by the convection of hot fluids below Earth's crust.
A.5. Features on the ocean floor are highly varied, and include trenches, rift valleys, mid-ocean ridges, seamounts, islands, and continental shelves.
A.7. During various times in Earth's geologic history, all of the continents have been joined into one "super continent." A giant ocean circulated around the supercontinent.
A.8. The supercontinent broke apart along rift valleys to create new, smaller continents and ocean basins now known as the Pacific Ocean, Atlantic Ocean, etc.
A.9. The continents are still in motion today.
B. 97% of all water on Earth is ocean water, which has unique chemical and physical properties.
B.1. Salts enter the ocean via erosion from land, volcanic emissions, reactions at the sea floor, and atmospheric deposition.
B.2. The freezing point of ocean water decreases as salinity increases; the pH of ocean water is more basic than fresh water.
B.3. Density differences between masses of water can cause currents.
B.4. The density of ocean water increases as salinity (amount of dissolved salts) increases and as temperature decreases.
B.5. The salinity of ocean water can change due to adding or removing water (e.g., evaporation, melting glaciers, or inflow from rivers, streams, and rainfall).
B.6. The temperature of ocean water can change due to warming and cooling (e.g., heat from the sun or contact with ice).
C. The ocean is one interconnected body of water that is integral to the water cycle; and is in constant motion in a global circulation system.
C.1. A global ocean circulation system is generated from tides and different types of currents moving the water.
C.2. Deep ocean currents are driven by density differences between masses of ocean water.
C.3. The wind, combined with Earth's rotation (Coriolis effect), drives surface currents in circular gyres in each ocean basin; clockwise in the Northern Hemisphere and counter-clockwise in the Southern Hemisphere.
C.4. Tides are mainly caused by the gravitational interaction between Earth, the moon and the sun.
C.5. Ocean circulation is influenced by the position of basins, continents, and other geologic features.
C.6. Currents transport heat, nutrients, and organisms throughout the ocean.
C.7. Upwelling, which occurs mostly on west coasts, brings nutrients from deep water to the sunlit surface zone where photosynthetic primary producers grow.
C.8. Currents are especially important in moving young organisms (larvae and juveniles) to populate new areas.
C.9. All major watersheds, from the Amazon River to melting glaciers, mix fresh and salt water when they meet the ocean, which contributes to the density differences that set ocean currents in motion.
C.10. As water travels through the watersheds, it collects nutrients, salts, sediments and pollutants and carries them into the ocean.
C.11. Sea level rises as glaciers melt.
See Principle 2: A19
See Principle 7: A2
See Principle 3: A1
See Principle 5: A8
See Principle 5: B11
See Principle 6: D17
See Principle 2: A15

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

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

Geologic Features — A

The size and shape of the ocean has changed over geologic time and continues to move and change.

A1	Motion along the margins of lithospheric plates creates physical features on the ocean floor and land.
A7	During various times in Earth's geologic history, all of the continents have been joined into one supercontinent. A giant ocean circulated around the supercontinent.
A2	Many of the physical features on the ocean floor are the result of the constant motion of the lithospheric plates that make up Earth's crust.
A8	The supercontinent broke apart along rift valleys to create new, smaller continents and ocean basins now known as the Pacific Ocean, Atlantic Ocean, etc.
A3	New lithospheric crust is generated at spreading centers while older, denser crust is recycled into the Earth's interior at subduction zones, creating various physical features.
A4	Plate movement is primarily caused by the convection of hot fluids below Earth's crust.
A5	Features on the ocean floor are highly varied, and include trenches, rift valleys, mid-ocean ridges, seamounts, islands, and continental shelves.
A9	The continents are still in motion today.

Properties of Ocean Water — B

97% of all water on Earth is ocean water, which has unique chemical and physical properties.

B1	Salts enter the ocean via erosion from land, volcanic emissions, reactions at the sea floor, and atmospheric deposition.
B3	Density differences between masses of water can cause currents.
B2	The freezing point of ocean water decreases as salinity increases; the pH of ocean water is more basic than fresh water.
B4	The density of ocean water increases as salinity (amount of dissolved salts) increases and as temperature decreases.
B5	The salinity of ocean water can change due to adding or removing water (e.g., evaporation, melting glaciers, or inflow from rivers, streams, and rainfall).
B6	The temperature of ocean water can change due to warming and cooling (e.g., heat from the sun or contact with ice).

Ocean Circulation — C

The ocean is one interconnected body of water that is integral to the water cycle; and is in constant motion in a global circulation system.

C1	A global ocean circulation system is generated from tides and different types of currents moving the water.
C6	Currents transport heat, nutrients, and organisms throughout the ocean.
C9	All major watersheds, from the Amazon River to melting glaciers, mix fresh and salt water when they meet the ocean, which contributes to the density differences that set ocean currents in motion.
C2	Deep ocean currents are driven by density differences between masses of ocean water.
C3	The wind, combined with Earth's rotation (Coriolis effect), drives surface currents in circular gyres in each ocean basin; clockwise in the Northern Hemisphere and counter-clockwise in the Southern Hemisphere.
C4	Tides are mainly caused by the gravitational interaction between Earth, the moon and the sun.
C7	Upwelling, which occurs mostly on west coasts, brings nutrients from deep water to the sunlit surface zone where photosynthetic primary producers grow.
C8	Currents are especially important in moving young organisms (larvae and juveniles) to populate new areas.
C10	As water travels through the watersheds, it collects nutrients, salts, sediments and pollutants and carries them into the ocean.
C11	Sea level rises as glaciers melt.
C5	Ocean circulation is influenced by the position of basins, continents, and other geologic features.
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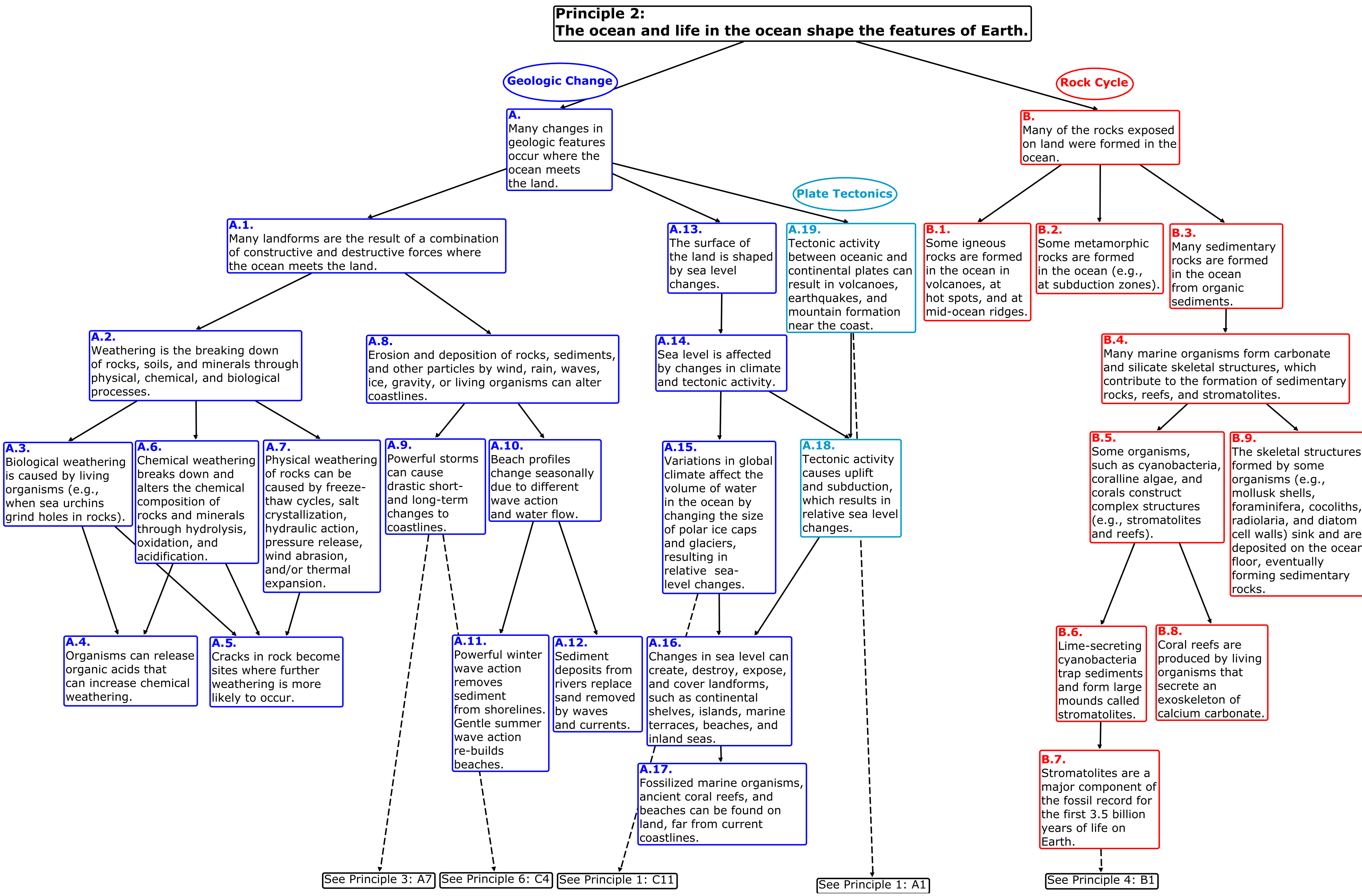
C5	Ocean circulation is influenced by the position of basins, continents, and other geologic features.


Principle 2:
The ocean and life in the ocean shape the features of Earth.
Geologic Change
Rock Cycle
Plate Tectonics
A.
Many changes in geologic features occur where the ocean meets the land.
B.
Many of the rocks exposed on land were formed in the ocean.
A.1.
Many landforms are the result of a combination of constructive and destructive forces where the ocean meets the land.
A.13.
The surface of the land is shaped by sea level changes.
A.19.
Tectonic activity between oceanic and continental plates can result in volcanoes, earthquakes, and mountain formation near the coast.
B.1.
Some igneous rocks are formed in the ocean in volcanoes, at hot spots, and at mid-ocean ridges.
B.2.
Some metamorphic rocks are formed in the ocean (e.g., at subduction zones).
B.3.
Many sedimentary rocks are formed in the ocean from organic sediments.
A.2.
Weathering is the breaking down of rocks, soils, and minerals through physical, chemical, and biological processes.
A.8.
Erosion and deposition of rocks, sediments, and other particles by wind, rain, waves, ice, gravity, or living organisms can alter coastlines.
A.14.
Sea level is affected by changes in climate and tectonic activity.
B.4.
Many marine organisms form carbonate and silicate skeletal structures, which contribute to the formation of sedimentary rocks, reefs, and stromatolites.
A.3.
Biological weathering is caused by living organisms (e.g., when sea urchins grind holes in rocks).
A.6.
Chemical weathering breaks down and alters the chemical composition of rocks and minerals through hydrolysis, oxidation, and acidification.
A.7.
Physical weathering of rocks can be caused by freeze-thaw cycles, salt crystallization, hydraulic action, pressure release, wind abrasion, and/or thermal expansion.
A.9.
Powerful storms can cause drastic short- and long-term changes to coastlines.
A.10.
Beach profiles change seasonally due to different wave action and water flow.
A.15.
Variations in global climate affect the volume of water in the ocean by changing the size of polar ice caps and glaciers, resulting in relative sea-level changes.
A.18.
Tectonic activity causes uplift and subduction, which results in relative sea level changes.
B.5.
Some organisms, such as cyanobacteria, coralline algae, and corals construct complex structures (e.g., stromatolites and reefs).
B.9.
The skeletal structures formed by some organisms (e.g., mollusk shells, foraminifera, cocoliths, radiolaria, and diatom cell walls) sink and are deposited on the ocean floor, eventually forming sedimentary rocks.
A.4.
Organisms can release organic acids that can increase chemical weathering.
A.5.
Cracks in rock become sites where further weathering is more likely to occur.
A.11.
Powerful winter wave action removes sediment from shorelines. Gentle summer wave action re-builds beaches.
A.12.
Sediment deposits from rivers replace sand removed by waves and currents.
A.16.
Changes in sea level can create, destroy, expose, and cover landforms, such as continental shelves, islands, marine terraces, beaches, and inland seas.
B.6.
Lime-secreting cyanobacteria trap sediments and form large mounds called stromatolites.
B.8.
Coral reefs are produced by living organisms that secrete an exoskeleton of calcium carbonate.
A.17.
Fossilized marine organisms, ancient coral reefs, and beaches can be found on land, far from current coastlines.
B.7.
Stromatolites are a major component of the fossil record for the first 3.5 billion years of life on Earth.
See Principle 3: A7
See Principle 6: C4
See Principle 1: C11
See Principle 1: A1
See Principle 4: B1

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

Geologic Change — A

Many changes in geologic features occur where the ocean meets the land.

A1
Many landforms are the result of a combination of constructive and destructive forces where the ocean meets the land.

- **A2** — Weathering is the breaking down of rocks, soils, and minerals through physical, chemical, and biological processes.
  - **A3** — Biological weathering is caused by living organisms (e.g., when sea urchins grind holes in rocks).
    - **A4** — Organisms can release organic acids that can increase chemical weathering.
    - **A5** — Cracks in rock become sites where further weathering is more likely to occur.
  - **A6** — Chemical weathering breaks down and alters the chemical composition of rocks and minerals through hydrolysis, oxidation, and acidification.
    - **A4** — Organisms can release organic acids that can increase chemical weathering.
    - **A5** — Cracks in rock become sites where further weathering is more likely to occur.
  - **A7** — Physical weathering of rocks can be caused by freeze-thaw cycles, salt crystallization, hydraulic action, pressure release, wind abrasion, and/or thermal expansion.
    - **A5** — Cracks in rock become sites where further weathering is more likely to occur.
- **A8** — Erosion and deposition of rocks, sediments, and other particles by wind, rain, waves, ice, gravity, or living organisms can alter coastlines.
  - **A9** — Powerful storms can cause drastic short- and long-term changes to coastlines.
  - **A10** — Beach profiles change seasonally due to different wave action and water flow.
    - **A11** — Powerful winter wave action removes sediment from shorelines. Gentle summer wave action re-builds beaches.
    - **A12** — Sediment deposits from rivers replace sand removed by waves and currents.

A13
The surface of the land is shaped by sea level changes.

- **A14** — Sea level is affected by changes in climate and tectonic activity.
  - **A15** — Variations in global climate affect the volume of water in the ocean by changing the size of polar ice caps and glaciers, resulting in relative sea-level changes.
    - **A16** — Changes in sea level can create, destroy, expose, and cover landforms, such as continental shelves, islands, marine terraces, beaches, and inland seas.
      - **A17** — Fossilized marine organisms, ancient coral reefs, and beaches can be found on land, far from current coastlines.
  - **A18** — Tectonic activity causes uplift and subduction, which results in relative sea level changes.
    - **A16** — Changes in sea level can create, destroy, expose, and cover landforms, such as continental shelves, islands, marine terraces, beaches, and inland seas.
      - **A17** — Fossilized marine organisms, ancient coral reefs, and beaches can be found on land, far from current coastlines.

Plate Tectonics — A19
Tectonic activity between oceanic and continental plates can result in volcanoes, earthquakes, and mountain formation near the coast.

- **A18** — Tectonic activity causes uplift and subduction, which results in relative sea level changes.
  - **A16** — Changes in sea level can create, destroy, expose, and cover landforms, such as continental shelves, islands, marine terraces, beaches, and inland seas.
    - **A17** — Fossilized marine organisms, ancient coral reefs, and beaches can be found on land, far from current coastlines.

Rock Cycle — B

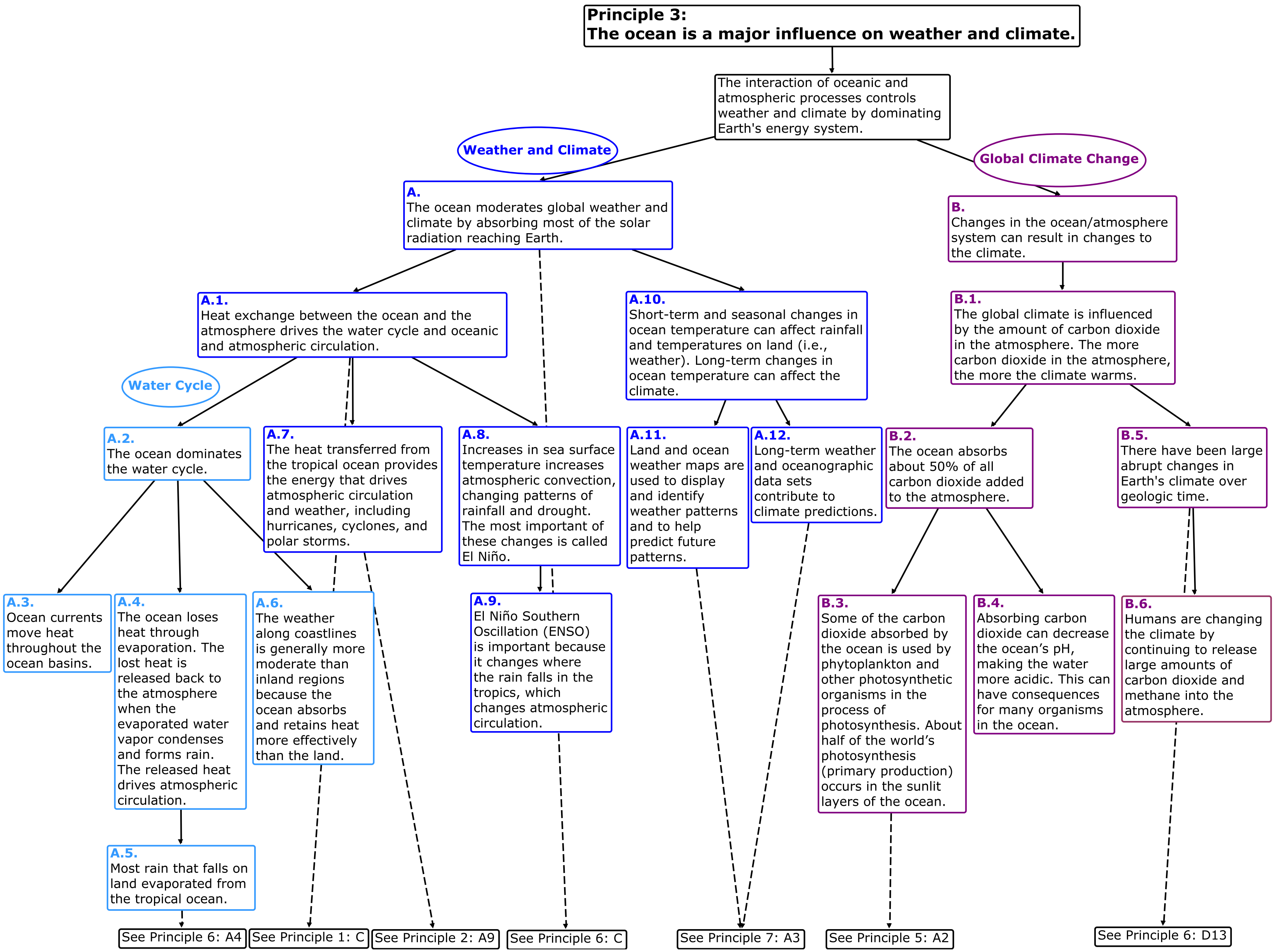
Many of the rocks exposed on land were formed in the ocean.

B1
Some igneous rocks are formed in the ocean in volcanoes, at hot spots, and at mid-ocean ridges.

B2
Some metamorphic rocks are formed in the ocean (e.g., at subduction zones).

B3
Many sedimentary rocks are formed in the ocean from organic sediments.

- **B4** — Many marine organisms form carbonate and silicate skeletal structures, which contribute to the formation of sedimentary rocks, reefs, and stromatolites.
  - **B5** — Some organisms, such as cyanobacteria, coralline algae, and corals construct complex structures (e.g., stromatolites and reefs).
    - **B6** — Lime-secreting cyanobacteria trap sediments and form large mounds called stromatolites.
      - **B7** — Stromatolites are a major component of the fossil record for the first 3.5 billion years of life on Earth.
    - **B8** — Coral reefs are produced by living organisms that secrete an exoskeleton of calcium carbonate.
  - **B9** — The skeletal structures formed by some organisms (e.g., mollusk shells, foraminifera, cocoliths, radiolaria, and diatom cell walls) sink and are deposited on the ocean floor, eventually forming sedimentary rocks.


Principle 3:
The ocean is a major influence on weather and climate.
The interaction of oceanic and atmospheric processes controls weather and climate by dominating Earth's energy system.
Weather and Climate
Global Climate Change
A.
The ocean moderates global weather and climate by absorbing most of the solar radiation reaching Earth.
B.
Changes in the ocean/atmosphere system can result in changes to the climate.
A.1.
Heat exchange between the ocean and the atmosphere drives the water cycle and oceanic and atmospheric circulation.
A.10.
Short-term and seasonal changes in ocean temperature can affect rainfall and temperatures on land (i.e., weather). Long-term changes in ocean temperature can affect the climate.
B.1.
The global climate is influenced by the amount of carbon dioxide in the atmosphere. The more carbon dioxide in the atmosphere, the more the climate warms.
Water Cycle
A.2.
The ocean dominates the water cycle.
A.7.
The heat transferred from the tropical ocean provides the energy that drives atmospheric circulation and weather, including hurricanes, cyclones, and polar storms.
A.8.
Increases in sea surface temperature increases atmospheric convection, changing patterns of rainfall and drought. The most important of these changes is called El Niño.
A.11.
Land and ocean weather maps are used to display and identify weather patterns and to help predict future patterns.
A.12.
Long-term weather and oceanographic data sets contribute to climate predictions.
B.2.
The ocean absorbs about 50% of all carbon dioxide added to the atmosphere.
B.5.
There have been large abrupt changes in Earth's climate over geologic time.
A.3.
Ocean currents move heat throughout the ocean basins.
A.4.
The ocean loses heat through evaporation. The lost heat is released back to the atmosphere when the evaporated water vapor condenses and forms rain. The released heat drives atmospheric circulation.
A.6.
The weather along coastlines is generally more moderate than inland regions because the ocean absorbs and retains heat more effectively than the land.
A.9.
El Niño Southern Oscillation (ENSO) is important because it changes where the rain falls in the tropics, which changes atmospheric circulation.
B.3.
Some of the carbon dioxide absorbed by the ocean is used by phytoplankton and other photosynthetic organisms in the process of photosynthesis. About half of the world's photosynthesis (primary production) occurs in the sunlit layers of the ocean.
B.4.
Absorbing carbon dioxide can decrease the ocean's pH, making the water more acidic. This can have consequences for many organisms in the ocean.
B.6.
Humans are changing the climate by continuing to release large amounts of carbon dioxide and methane into the atmosphere.
A.5.
Most rain that falls on land evaporated from the tropical ocean.
See Principle 6: A4
See Principle 1: C
See Principle 2: A9
See Principle 6: C
See Principle 7: A3
See Principle 5: A2
See Principle 6: D13

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

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

Weather and Climate — A

The ocean moderates global weather and climate by absorbing most of the solar radiation reaching Earth.

A1

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

Water Cycle — A2

The ocean dominates the water cycle.

A3

Ocean currents move heat throughout the ocean basins.

A4

The ocean loses heat through evaporation. The lost heat is released back to the atmosphere when the evaporated water vapor condenses and forms rain. The released heat drives atmospheric circulation.

A5

Most rain that falls on land evaporated from the tropical ocean.

A6

The weather along coastlines is generally more moderate than inland regions because the ocean absorbs and retains heat more effectively than the land.

A7

The heat transferred from the tropical ocean provides the energy that drives atmospheric circulation and weather, including hurricanes, cyclones, and polar storms.

A8

Increases in sea surface temperature increases atmospheric convection, changing patterns of rainfall and drought. The most important of these changes is called El Niño.

A9

El Niño Southern Oscillation (ENSO) is important because it changes where the rain falls in the tropics, which changes atmospheric circulation.

A10

Short-term and seasonal changes in ocean temperature can affect rainfall and temperatures on land (i.e., weather). Long-term changes in ocean temperature can affect the climate.

A11

Land and ocean weather maps are used to display and identify weather patterns and to help predict future patterns

A12

Longterm weather and oceanographic data sets contribute to climate predictions.

Global Climate Change — B

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

B1

The global climate is influenced by the amount of carbon dioxide in the atmosphere. The more carbon dioxide in the atmosphere, the more the climate warms.

B2

The ocean absorbs about 50% of all carbon dioxide added to the atmosphere.

B3

Some of the carbon dioxide absorbed by the ocean is used by phytoplankton and other photosynthetic organisms in the process of photosynthesis. About half of the world's photosynthesis (primary production) occurs in the sunlit layers of the ocean.

B4

Absorbing carbon dioxide can decrease the ocean's pH, making the water more acidic. This can have consequences for many organisms in the ocean.

B5

There have been large abrupt changes in Earth's climate over geologic time.

B6

Humans are changing the climate by continuing to release large amounts of carbon dioxide and methane into the atmosphere.

Principle 4: The ocean makes Earth habitable.

Oxygen Production

A. Originally, all oxygen in the atmosphere came from photosynthetic organisms in the ocean.

A.1. Earth originally had an atmosphere containing gases toxic to most organisms; there was no life on land until oxygen became common in the atmosphere.

A.2. Cyanobacteria (blue-green algae) living in the ocean generated oxygen in Earth's atmosphere through the process of photosynthesis, over many millions of years.

A.3. The oxygen produced by cyanobacteria through photosynthesis first accumulated in the ocean, and then escaped into the atmosphere, where it formed ozone that blocked much UV radiation from reaching Earth's surface.

A.4. By 550 million years ago, oxygen and ozone levels in the atmosphere were high enough that terrestrial organisms could develop and survive.

A.5. Most of the oxygen consumed by organisms living on land and in the water is produced by photosynthetic organisms in the ocean.

A.6. The process of photosynthesis produces oxygen gas, while respiration and decay use oxygen.

Origins of Life

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

B.1. The fossil record of ancient lifeforms provides evidence for the theory of evolution and the important role that the ocean played in the evolution of life on Earth.

B.2. Cyanobacteria (blue-green algae), the ancestors of all plants and algae, are among the oldest fossils currently known on Earth. These 3 billion-year-old organisms evolved in the ocean, and are found in ancient ocean sediments.

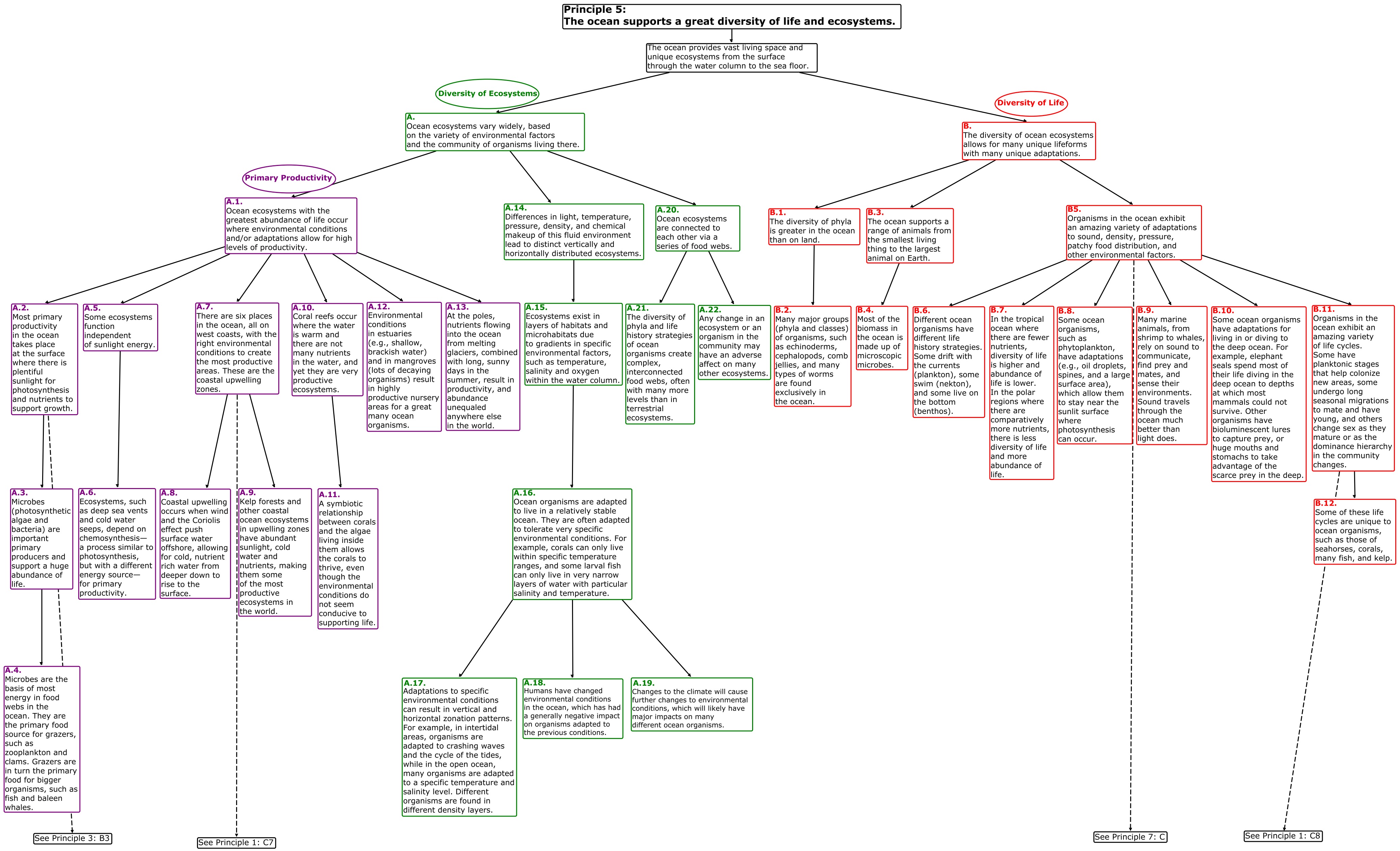
B.3. The chloroplast, which plants use to make food for themselves through photosynthesis, is a remnant of cyanobacteria.

B.4. 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.

See Principle 2: B7

Principle 4: The ocean makes Earth habitable.

Ocean Production — A		Origins of Life — B	
Originally, all oxygen in the atmosphere came from photosynthetic organisms in the ocean.		Life started in the ocean, and the earliest evidence of life is found in ancient ocean sediments.	
A1	**A5**	**B1**	
Earth originally had an atmosphere containing gases toxic to most organisms; there was no life on land until oxygen became common in the atmosphere.	Most of the oxygen consumed by organisms living on land and in the water is produced by photosynthetic organisms in the ocean.	The fossil record of ancient lifeforms provides evidence for the theory of evolution and the important role that the ocean played in the evolution of life on Earth.	
A2	**A6**	**B2**	**B4**
Cyanobacteria (blue-green algae) living in the ocean generated oxygen in Earth's atmosphere through the process of photosynthesis, over many millions of years.	The process of photosynthesis produces oxygen gas, while respiration and decay use oxygen.	Cyanobacteria (blue-green algae), the ancestors of all plants and algae, are among the oldest fossils currently known on Earth. These 3 billion-year-old organisms evolved in the ocean, and are found in ancient ocean sediments.	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.
A3		**B3**	
The oxygen produced by cyanobacteria through photosynthesis first accumulated in the ocean, and then escaped into the atmosphere, where it formed ozone that blocked much UV radiation from reaching Earth's surface.		The chloroplast, which plants use to make food for themselves through photosynthesis, is a remnant of cyanobacteria.	
A4			
By 550 million years ago, oxygen and ozone levels in the atmosphere were high enough that terrestrial organisms could develop and survive.			



Principle 5:
The ocean supports a great diversity of life and ecosystems.
The ocean provides vast living space and unique ecosystems from the surface through the water column to the sea floor.
Diversity of Ecosystems
A. Ocean ecosystems vary widely, based on the variety of environmental factors and the community of organisms living there.
Diversity of Life
B. The diversity of ocean ecosystems allows for many unique lifeforms with many unique adaptations.
Primary Productivity
A.1. Ocean ecosystems with the greatest abundance of life occur where environmental conditions and/or adaptations allow for high levels of productivity.
A.14. Differences in light, temperature, pressure, density, and chemical makeup of this fluid environment lead to distinct vertically and horizontally distributed ecosystems.
A.20. Ocean ecosystems are connected to each other via a series of food webs.
B.1. The diversity of phyla is greater in the ocean than on land.
B.3. The ocean supports a range of animals from the smallest living thing to the largest animal on Earth.
B5. Organisms in the ocean exhibit an amazing variety of adaptations to sound, density, pressure, patchy food distribution, and other environmental factors.
A.2. Most primary productivity in the ocean takes place at the surface where there is plentiful sunlight for photosynthesis and nutrients to support growth.
A.5. Some ecosystems function independent of sunlight energy.
A.7. There are six places in the ocean, all on west coasts, with the right environmental conditions to create the most productive areas. These are the coastal upwelling zones.
A.10. Coral reefs occur where the water is warm and there are not many nutrients in the water, and yet they are very productive ecosystems.
A.12. Environmental conditions in estuaries (e.g., shallow, brackish water) and in mangroves (lots of decaying organisms) result in highly productive nursery areas for a great many ocean organisms.
A.13. At the poles, nutrients flowing into the ocean from melting glaciers, combined with long, sunny days in the summer, result in productivity, and abundance unequaled anywhere else in the world.
A.15. Ecosystems exist in layers of habitats and microhabitats due to gradients in specific environmental factors, such as temperature, salinity and oxygen within the water column.
A.21. The diversity of phyla and life history strategies of ocean organisms create complex, interconnected food webs, often with many more levels than in terrestrial ecosystems.
A.22. Any change in an ecosystem or an organism in the community may have an adverse affect on many other ecosystems.
B.2. Many major groups (phyla and classes) of organisms, such as echinoderms, cephalopods, comb jellies, and many types of worms are found exclusively in the ocean.
B.4. Most of the biomass in the ocean is made up of microscopic microbes.
B.6. Different ocean organisms have different life history strategies. Some drift with the currents (plankton), some swim (nekton), and some live on the bottom (benthos).
B.7. In the tropical ocean where there are fewer nutrients, diversity of life is higher and abundance of life is lower. In the polar regions where there are comparatively more nutrients, there is less diversity of life and more abundance of life.
B.8. Some ocean organisms, such as phytoplankton, have adaptations (e.g., oil droplets, spines, and a large surface area), which allow them to stay near the sunlit surface where photosynthesis can occur.
B.9. Many marine animals, from shrimp to whales, rely on sound to communicate, find prey and mates, and sense their environments. Sound travels through the ocean much better than light does.
B.10. Some ocean organisms have adaptations for living in or diving to the deep ocean. For example, elephant seals spend most of their life diving in the deep ocean to depths at which most mammals could not survive. Other organisms have bioluminescent lures to capture prey, or huge mouths and stomachs to take advantage of the scarce prey in the deep.
B.11. Organisms in the ocean exhibit an amazing variety of life cycles. Some have planktonic stages that help colonize new areas, some undergo long seasonal migrations to mate and have young, and others change sex as they mature or as the dominance hierarchy in the community changes.
A.3. Microbes (photosynthetic algae and bacteria) are important primary producers and support a huge abundance of life.
A.6. Ecosystems, such as deep sea vents and cold water seeps, depend on chemosynthesis—a process similar to photosynthesis, but with a different energy source—for primary productivity.
A.8. Coastal upwelling occurs when wind and the Coriolis effect push surface water offshore, allowing for cold, nutrient rich water from deeper down to rise to the surface.
A.9. Kelp forests and other coastal ocean ecosystems in upwelling zones have abundant sunlight, cold water and nutrients, making them some of the most productive ecosystems in the world.
A.11. A symbiotic relationship between corals and the algae living inside them allows the corals to thrive, even though the environmental conditions do not seem conducive to supporting life.
A.16. Ocean organisms are adapted to live in a relatively stable ocean. They are often adapted to tolerate very specific environmental conditions. For example, corals can only live within specific temperature ranges, and some larval fish can only live in very narrow layers of water with particular salinity and temperature.
B.12. Some of these life cycles are unique to ocean organisms, such as those of seahorses, corals, many fish, and kelp.
A.4. Microbes are the basis of most energy in food webs in the ocean. They are the primary food source for grazers, such as zooplankton and clams. Grazers are in turn the primary food for bigger organisms, such as fish and baleen whales.
A.17. Adaptations to specific environmental conditions can result in vertical and horizontal zonation patterns. For example, in intertidal areas, organisms are adapted to crashing waves and the cycle of the tides, while in the open ocean, many organisms are adapted to a specific temperature and salinity level. Different organisms are found in different density layers.
A.18. Humans have changed environmental conditions in the ocean, which has had a generally negative impact on organisms adapted to the previous conditions.
A.19. Changes to the climate will cause further changes to environmental conditions, which will likely have major impacts on many different ocean organisms.
See Principle 3: B3
See Principle 1: C7
See Principle 7: C
See Principle 1: C8

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

The ocean provides a vast living space and unique ecosystems, from the surface, through the water column, to the sea floor.

Diversity of Ecosystem — A

Ocean ecosystems vary widely, based on the variety of environmental factors and the community of organisms living there.

Primary Productivity — A1

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

- **A2**: Most primary productivity in the ocean takes place at the surface where there is plentiful sunlight for photosynthesis and nutrients for growth.
  - **A3**: Microbes (photosynthetic algae and bacteria) are important primary producers and support a huge abundance of life.
    - **A4**: Microbes are the basis of most energy in food webs in the ocean. They are the primary food source for grazers, such as zooplankton and clams. Grazers are in turn the primary food for bigger organisms, such as fish and baleen whales.
- **A5**: Some ecosystems function independent of light energy.
  - **A6**: Ecosystems, such as deep sea vents and cold water seeps depend on chemosynthesis — a process similar to photosynthesis, but with a different energy source — for primary productivity.
- **A7**: There are six places in the ocean, all on west coasts, with the right environmental conditions to create the most productive areas. These are the coastal upwelling zones.
  - **A8**: Coastal upwelling occurs when wind and the Coriolis effect push surface water offshore, allowing for cold nutrient water from deeper down to rise to the surface
  - **A9**: Kelp forests and other coastal ocean ecosystems in upwelling zones have abundant sunlight, cold water, and nutrients, making them some of the most productive ecosystems in the world
- **A10**: Coral reefs occur where the water is warm and there are not many nutrients in the water, and yet they are very productive ecosystems.
  - **A11**: A symbiotic relationship between corals and the algae living inside them allows the corals to thrive, even though the environmental conditions do not seem conducive to supporting life.
- **A12**: Environmental conditions in estuaries (e.g., shallow, brackish water) and in mangroves (lots of decaying organisms) result in highly productive nursery areas for a great many ocean organisms.
- **A13**: At the poles, nutrients flowing into the ocean from melting glaciers, combined with long, sunny days in the summer, result in productivity, and abundance unequaled anywhere else in the world.

A14

Differences in light, temperature, pressure, density, and chemical makeup of this fluid environment lead to distinct vertically and horizontally distributed ecosystems

- **A15**: Ecosystems exist in layers of habitats and microhabitats due to gradients in specific environmental factors, such as temperature, salinity, and oxygen within the water column.
  - **A16**: Ocean organisms are adapted to live in a relatively stable ocean. They are often adapted to tolerate very specific environmental conditions. For example, corals can only live within specific temperature ranges, and some larval fish can only live in very narrow layers of water with particular salinity and temperature.
    - **A17**: Adaptations to specific environmental conditions can result in vertical and horizontal zonation patterns. For example, in intertidal areas, organisms are adapted to crashing waves and the cycle of the tides, while in the open ocean, many organisms are adapted to a specific temperature and salinity level. Different organisms are found in different density layers.
    - **A18**: Humans have changed environmental conditions in the ocean, which has had a generally negative impact on organisms adapted to the previous conditions.
    - **A19**: Changes to the climate will cause further changes to environmental conditions, which will likely have major impacts on many different ocean organisms.

A20

Ocean ecosystems are connected to each other via a series of food webs.

- **A21**: The diversity of phyla and life history strategies of ocean organisms create complex, interconnected food webs, often with many more levels than in terrestrial ecosystems.
- **A22**: Any change in an ecosystem or an organism in the community may have an adverse effect on many other ecosystems.

Diversity of Life — B

The diversity of ocean ecosystems allows for many unique lifeforms with many unique adaptations.

B1

The diversity of phyla is greater in the ocean than on land.

- **B2**: Many major groups (phyla and classes) of organisms, such as echinoderms, cephalopods, comb jellies, and many types of worms are found exclusively in the ocean.

B3

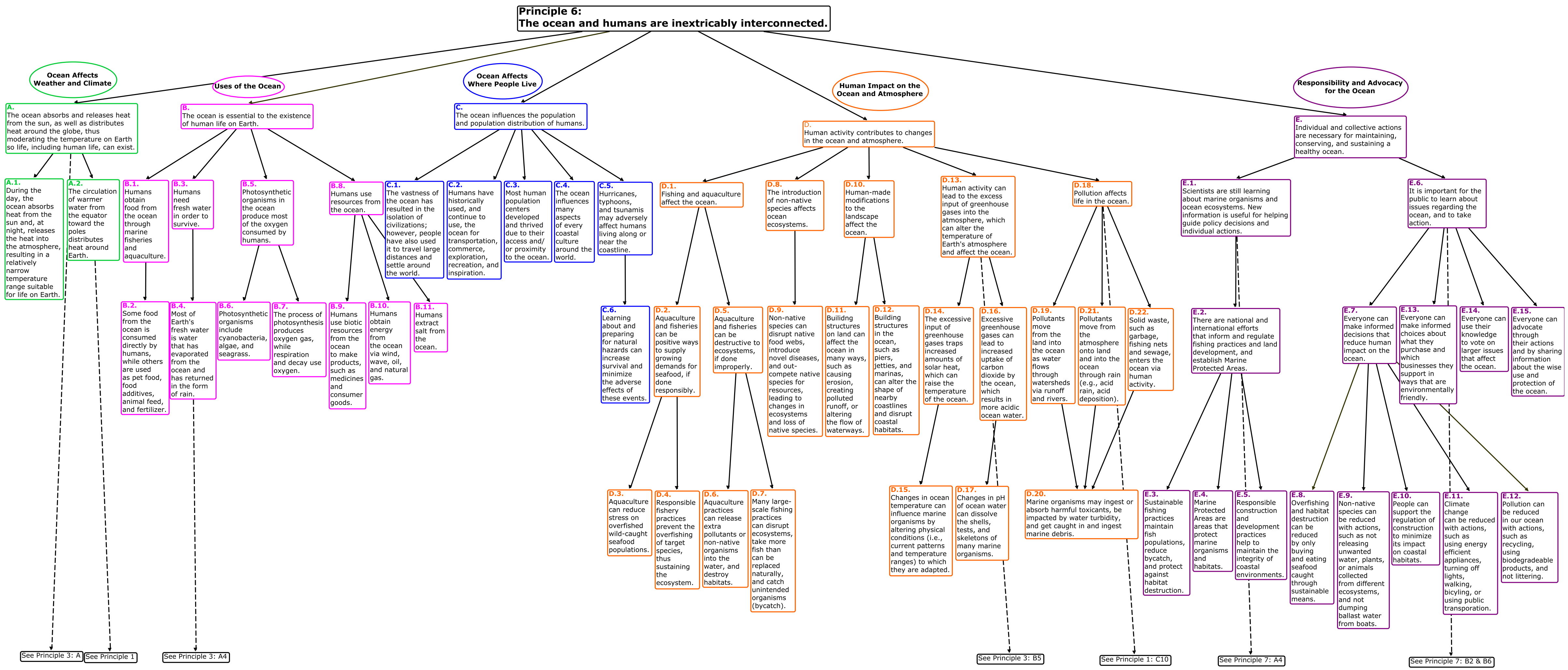
The ocean supports a range of animals from the smallest living thing to the largest animal on Earth.

- **B4**: Most of the biomass in the ocean is made up of microscopic microbes.

B5

Organisms in the ocean exhibit an amazing variety of adaptations to sound, density, pressure, patchy food distribution, and other environmental factors.

- **B6**: Different ocean organisms have different life history strategies. Some drift with the currents (plankton), some swim (nekton), and some live on the bottom (benthos).
- **B7**: "In the tropical ocean where there are fewer nutrients, diversity of life is higher and abundance of life is lower. In the polar regions where there are comparatively more nutrients, there is less diversity of life and more abundance of life.
- **B8**: Some ocean organisms such as phytoplankton have adaptations (e.g., oil droplets, spines, and a large surface area), which allow them to stay near the sunlit surface where photosynthesis can occur.
- **B9**: Many marine animals, from shrimp to whales, rely on sound to communicate, find prey and mates, and sense their environments. Sound travels through the ocean much better than light does.
- **B10**: Some ocean organisms have adaptations for living in or diving to the deep ocean. For example, elephant seals spend most of their life diving in the deep ocean to depths at which most mammals could not survive. Other organisms have bioluminescent lures to capture prey, or huge mouths and stomachs to take advantage of the scarce prey in the deep.
- **B11**: Organisms in the ocean exhibit an amazing variety of life cycles. Some have planktonic stages that help colonize new areas, some undergo long seasonal migrations to mate and have young, and others change sex as they mature or as the dominance hierarchy in the community changes.
  - **B12**: Some of these life cycles are unique to ocean organisms, such as those of seahorses, corals, many fish, and kelp.


Principle 6:
The ocean and humans are inextricably interconnected.
Ocean Affects Weather and Climate
A. The ocean absorbs and releases heat from the sun, as well as distributes heat around the globe, thus moderating the temperature on Earth so life, including human life, can exist.
A.1. During the day, the ocean absorbs heat from the sun and, at night, releases the heat into the atmosphere, resulting in a relatively narrow temperature range suitable for life on Earth.
A.2. The circulation of warmer water from the equator toward the poles distributes heat around Earth.
Uses of the Ocean
B. The ocean is essential to the existence of human life on Earth.
B.1. Humans obtain food from the ocean through marine fisheries and aquaculture.
B.2. Some food from the ocean is consumed directly by humans, while others are used as pet food, food additives, animal feed, and fertilizer.
B.3. Humans need fresh water in order to survive.
B.4. Most of Earth's fresh water is water that has evaporated from the ocean and has returned in the form of rain.
B.5. Photosynthetic organisms in the ocean produce most of the oxygen consumed by humans.
B.6. Photosynthetic organisms include cyanobacteria, algae, and seagrass.
B.7. The process of photosynthesis produces oxygen gas, while respiration and decay use oxygen.
B.8. Humans use resources from the ocean.
B.9. Humans use biotic resources from the ocean to make products, such as medicines and consumer goods.
B.10. Humans obtain energy from the ocean via wind, wave, oil, and natural gas.
B.11. Humans extract salt from the ocean.
Ocean Affects Where People Live
C. The ocean influences the population and population distribution of humans.
C.1. The vastness of the ocean has resulted in the isolation of civilizations; however, people have also used it to travel large distances and settle around the world.
C.2. Humans have historically used, and continue to use, the ocean for transportation, commerce, exploration, recreation, and inspiration.
C.3. Most human population centers developed and thrived due to their access and/or proximity to the ocean.
C.4. The ocean influences many aspects of every coastal culture around the world.
C.5. Hurricanes, typhoons, and tsunamis may adversely affect humans living along or near the coastline.
C.6. Learning about and preparing for natural hazards can increase survival and minimize the adverse effects of these events.
Human Impact on the Ocean and Atmosphere
D. Human activity contributes to changes in the ocean and atmosphere.
D.1. Fishing and aquaculture affect the ocean.
D.2. Aquaculture and fisheries can be positive ways to supply growing demands for seafood, if done responsibly.
D.3. Aquaculture can reduce stress on overfished wild-caught seafood populations.
D.4. Responsible fishery practices prevent the overfishing of target species, thus sustaining the ecosystem.
D.5. Aquaculture and fisheries can be destructive to ecosystems, if done improperly.
D.6. Aquaculture practices can release extra pollutants or non-native organisms into the water, and destroy habitats.
D.7. Many large-scale fishing practices can disrupt ecosystems, take more fish than can be replaced naturally, and catch unintended organisms (bycatch).
D.8. The introduction of non-native species affects ocean ecosystems.
D.9. Non-native species can disrupt native food webs, introduce novel diseases, and out-compete native species for resources, leading to changes in ecosystems and loss of native species.
D.10. Human-made modifications to the landscape affect the ocean.
D.11. Builidng structures on land can affect the ocean in many ways, such as causing erosion, creating polluted runoff, or altering the flow of waterways.
D.12. Building structures in the ocean, such as piers, jetties, and marinas, can alter the shape of nearby coastlines and disrupt coastal habitats.
D.13. Human activity can lead to the excess input of greenhouse gases into the atmosphere, which can alter the temperature of Earth's atmosphere and affect the ocean.
D.14. The excessive input of greenhouse gases traps increased amounts of solar heat, which can raise the temperature of the ocean.
D.15. Changes in ocean temperature can influence marine organisms by altering physical conditions (i.e., current patterns and temperature ranges) to which they are adapted.
D.16. Excessive greenhouse gases can lead to increased uptake of carbon dioxide by the ocean, which results in more acidic ocean water.
D.17. Changes in pH of ocean water can dissolve the shells, tests, and skeletons of many marine organisms.
D.18. Pollution affects life in the ocean.
D.19. Pollutants move from the land into the ocean as water flows through watersheds via runoff and rivers.
D.20. Marine organisms may ingest or absorb harmful toxicants, be impacted by water turbidity, and get caught in and ingest marine debris.
D.21. Pollutants move from the atmosphere onto land and into the ocean through rain (e.g., acid rain, acid deposition).
D.22. Solid waste, such as garbage, fishing nets and sewage, enters the ocean via human activity.
Responsibility and Advocacy for the Ocean
E. Individual and collective actions are necessary for maintaining, conserving, and sustaining a healthy ocean.
E.1. Scientists are still learning about marine organisms and ocean ecosystems. New information is useful for helping guide policy decisions and individual actions.
E.2. There are national and international efforts that inform and regulate fishing practices and land development, and establish Marine Protected Areas.
E.3. Sustainable fishing practices maintain fish populations, reduce bycatch, and protect against habitat destruction.
E.4. Marine Protected Areas are areas that protect marine organisms and habitats.
E.5. Responsible construction and development practices help to maintain the integrity of coastal environments.
E.6. It is important for the public to learn about issues regarding the ocean, and to take action.
E.7. Everyone can make informed decisions that reduce human impact on the ocean.
E.8. Overfishing and habitat destruction can be reduced by only buying and eating seafood caught through sustainable means.
E.9. Non-native species can be reduced with actions, such as not releasing unwanted water, plants, or animals collected from different ecosystems, and not dumping ballast water from boats.
E.10. People can support the regulation of construction to minimize its impact on coastal habitats.
E.11. Climate change can be reduced with actions, such as using energy efficient appliances, turning off lights, walking, bicyling, or using public transporation.
E.12. Pollution can be reduced in our ocean with actions, such as recycling, using biodegradeable products, and not littering.
E.13. Everyone can make informed choices about what they purchase and which businesses they support in ways that are environmentally friendly.
E.14. Everyone can use their knowledge to vote on larger issues that affect the ocean.
E.15. Everyone can advocate through their actions and by sharing information about the wise use and protection of the ocean.
See Principle 3: A
See Principle 1
See Principle 3: A4
See Principle 3: B5
See Principle 1: C10
See Principle 7: A4
See Principle 7: B2 & B6

Principle 6: The ocean and humans are inextricably interconnected.

Ocean Affects Weather and Climate — A

The ocean absorbs and releases heat from the sun, as well as distributes heat around the globe, thus moderating the temperature on Earth so life, including human life, can exist.

- **A1** During the day, the ocean absorbs heat from the sun and, at night, releases the heat into the atmosphere, resulting in a relatively narrow temperature range suitable for life on Earth.
- **A2** The circulation of warmer water from the equator toward the poles distributes heat around Earth.

Uses of the Ocean — B

The ocean is essential to the existence of human life on Earth.

- **B1** Humans obtain food from the ocean through marine fisheries and aquaculture.
  - **B2** Some food from the ocean is consumed directly by humans, while others are used as pet food, food additives, animal feed, and fertilizer.
- **B3** Humans need fresh water in order to survive.
  - **B4** Most of Earth's fresh water is water that has evaporated from the ocean and has returned in the form of rain.
- **B5** Photosynthetic organisms in the ocean produce most of the oxygen consumed by humans.
  - **B6** Photosynthetic organisms include cyanobacteria, algae, and seagrass.
  - **B7** The process of photosynthesis produces oxygen gas, while respiration and decay use oxygen.
- **B8** Humans use resources from the ocean.
  - **B9** Humans use biotic resources from the ocean to make products, such as medicines and consumer goods.
  - **B10** Humans obtain energy from the ocean via wind, wave, oil, and natural gas.
  - **B11** Humans extract salt from the ocean.

Ocean Affects Where People Live — C

The ocean influences the population and population distribution of humans.

- **C1** The vastness of the ocean has resulted in the isolation of civilizations; however, people have also used it to travel large distances and settle around the world.
- **C2** Humans have historically used, and continue to use the ocean for transportation, commerce, exploration, recreation, and inspiration.
- **C3** Most human population centers developed and thrived due to their access and/or proximity to the ocean.
- **C4** The ocean influences many aspects of every coastal culture around the world.
- **C5** Hurricanes, typhoons, and tsunamis may adversely affect humans living along or near the coastline.
  - **C6** Learning about and preparing for natural hazards can increase survival and minimize the adverse effects of these events.

Human Impact on the Ocean and Atmosphere — D

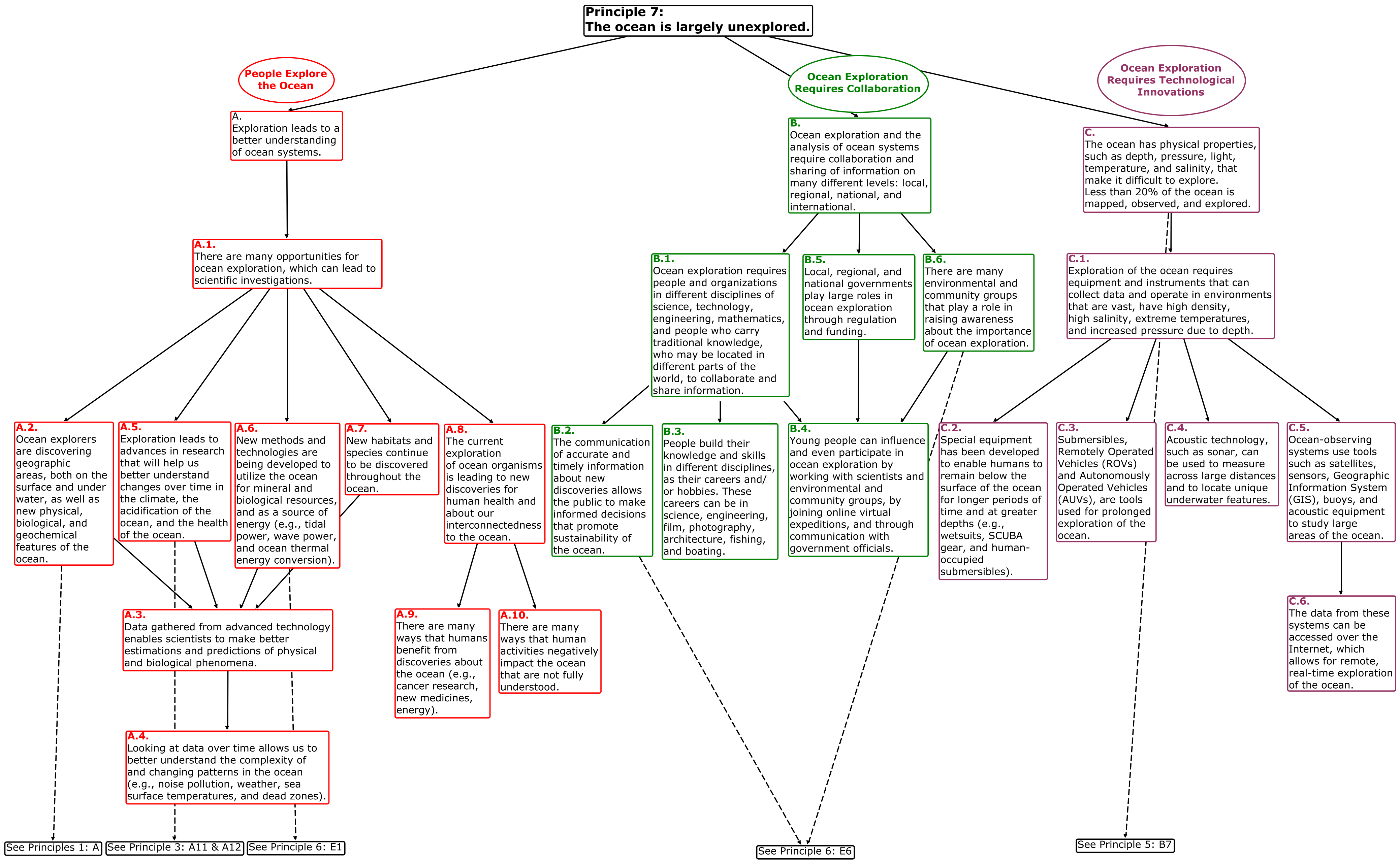
Human activity contributes to changes in the ocean and atmosphere.

- **D1** Fishing and aquaculture affect the ocean.
  - **D2** Aquaculture and fisheries can be positive ways to supply growing demands for seafood, if done responsibly.
    - **D3** Aquaculture can reduce stress on overfished wild-caught seafood populations.
    - **D4** Responsible fishery practices prevent the overfishing of target species, thus sustaining the ecosystem.
  - **D5** Aquaculture and fisheries can be destructive to ecosystems, if done improperly.
    - **D6** Aquaculture practices can release extra pollutants or non-native organisms into the water, and destroy habitats.
    - **D7** Many large-scale fishing practices can disrupt ecosystems, take more fish than can be replaced naturally and catch unintended organisms (bycatch).
- **D8** The introduction of non-native species affects ocean ecosystems.
  - **D9** Non-native species can disrupt native food webs, introduce novel diseases, and out-compete native species for resources, leading to changes in ecosystems and loss of native species.
- **D10** Human-made modifications to the landscape affect the ocean.
  - **D11** Building structures on land can affect the ocean in many ways, such as causing erosion, creating polluted runoff, or altering the flow of waterways.
  - **D12** Building structures in the ocean, such as piers, jetties, and marinas, can alter the shape of nearby coastlines and disrupt coastal habitats.
- **D13** Human activity can lead to the excess input of greenhouse gases into the atmosphere which can alter the temperature of Earth's atmosphere and affect the ocean.
  - **D14** The excessive input of greenhouse gases traps increased amounts of solar heat, which can raise the temperature of the ocean.
    - **D15** Changes in ocean temperature can influence marine organisms by altering physical conditions (i.e., current patterns and temperature ranges) to which they are adapted.
  - **D16** Excessive greenhouse gases can lead to increased uptake of carbon dioxide by the ocean, which results in more acidic ocean water.
    - **D17** Changes in pH of ocean water can dissolve the shells, tests, and skeletons of many marine organisms.
- **D18** Pollution affects life in the ocean.
  - **D19** Pollutants move from the land into the ocean as water flows through watersheds via runoff and rivers.
    - **D20** Marine organisms may ingest or absorb harmful toxicants, be impacted by water turbidity, and get caught in and ingest marine debris.
  - **D21** Pollutants move from the atmosphere onto land and into the ocean through rain (e.g., acid rain, acid deposition).
    - **D20** Marine organisms may ingest or absorb harmful toxicants, be impacted by water turbidity, and get caught in and ingest marine debris.
  - **D22** Solid waste, such as garbage, fishing nets, and sewage enters the ocean via human activity.
    - **D20** Marine organisms may ingest or absorb harmful toxicants, be impacted by water turbidity, and get caught in and ingest marine debris.

Responsibility and Advocacy for the Ocean — E

Individual and collective actions are necessary for maintaining, conserving, and sustaining a healthy ocean.

- **E1** Scientists are still learning about marine organisms and ocean ecosystems. New information is useful for helping guide policy decisions and individual actions.
  - **E2** There are national and international efforts that inform and regulate fishing practices and land development, and establish Marine Protected Areas.
    - **E3** Sustainable fishing practices maintain fish populations, reduce bycatch, and protect against habitat destruction.
    - **E4** Marine Protected Areas are areas that protect marine organisms and habitats.
    - **E5** Responsible construction and development practices help to maintain the integrity of coastal environments.
- **E6** It is important for the public to learn about issues regarding the ocean, and to take action.
  - **E7** Everyone can make informed decisions that reduce human impact on the ocean.
    - **E8** Overfishing and habitat destruction can be reduced by only buying and eating seafood caught through sustainable means.
    - **E9** Non-native species can be reduced with actions, such as not releasing unwanted water, plants, or animals collected from different ecosystems, and not dumping ballast water from boats.
    - **E10** People can support the regulation of construction to minimize its impact on coastal habitats.
    - **E11** Climate change can be reduced with actions, such as using energy efficient appliances, turning off lights, walking, biking, bicycling, or using public transportation.
    - **E12** Pollution can be reduced in our ocean with actions, such as recycling, using biodegradable products, and not littering.
  - **E13** Everyone can make informed choices about what they purchase and which businesses they support in ways that are environmentally friendly.
  - **E14** Everyone can use their knowledge to vote on larger issues that affect the ocean.
  - **E15** Everyone can advocate through their actions and by sharing information about the wise use and protection of the ocean.


Principle 7:
The ocean is largely unexplored.
People Explore the Ocean
Ocean Exploration Requires Collaboration
Ocean Exploration Requires Technological Innovations
A.
Exploration leads to a better understanding of ocean systems.
A.1.
There are many opportunities for ocean exploration, which can lead to scientific investigations.
A.2.
Ocean explorers are discovering geographic areas, both on the surface and under water, as well as new physical, biological, and geochemical features of the ocean.
A.5.
Exploration leads to advances in research that will help us better understand changes over time in the climate, the acidification of the ocean, and the health of the ocean.
A.6.
New methods and technologies are being developed to utilize the ocean for mineral and biological resources, and as a source of energy (e.g., tidal power, wave power, and ocean thermal energy conversion).
A.7.
New habitats and species continue to be discovered throughout the ocean.
A.8.
The current exploration of ocean organisms is leading to new discoveries for human health and about our interconnectedness to the ocean.
A.3.
Data gathered from advanced technology enables scientists to make better estimations and predictions of physical and biological phenomena.
A.4.
Looking at data over time allows us to better understand the complexity of and changing patterns in the ocean (e.g., noise pollution, weather, sea surface temperatures, and dead zones).
A.9.
There are many ways that humans benefit from discoveries about the ocean (e.g., cancer research, new medicines, energy).
A.10.
There are many ways that human activities negatively impact the ocean that are not fully understood.
B.
Ocean exploration and the analysis of ocean systems require collaboration and sharing of information on many different levels: local, regional, national, and international.
B.1.
Ocean exploration requires people and organizations in different disciplines of science, technology, engineering, mathematics, and people who carry traditional knowledge, who may be located in different parts of the world, to collaborate and share information.
B.5.
Local, regional, and national governments play large roles in ocean exploration through regulation and funding.
B.6.
There are many environmental and community groups that play a role in raising awareness about the importance of ocean exploration.
B.2.
The communication of accurate and timely information about new discoveries allows the public to make informed decisions that promote sustainability of the ocean.
B.3.
People build their knowledge and skills in different disciplines, as their careers and/or hobbies. These careers can be in science, engineering, film, photography, architecture, fishing, and boating.
B.4.
Young people can influence and even participate in ocean exploration by working with scientists and environmental and community groups, by joining online virtual expeditions, and through communication with government officials.
C.
The ocean has physical properties, such as depth, pressure, light, temperature, and salinity, that make it difficult to explore.
Less than 20% of the ocean is mapped, observed, and explored.
C.1.
Exploration of the ocean requires equipment and instruments that can collect data and operate in environments that are vast, have high density, high salinity, extreme temperatures, and increased pressure due to depth.
C.2.
Special equipment has been developed to enable humans to remain below the surface of the ocean for longer periods of time and at greater depths (e.g., wetsuits, SCUBA gear, and human-occupied submersibles).
C.3.
Submersibles, Remotely Operated Vehicles (ROVs) and Autonomously Operated Vehicles (AUVs), are tools used for prolonged exploration of the ocean.
C.4.
Acoustic technology, such as sonar, can be used to measure across large distances and to locate unique underwater features.
C.5.
Ocean-observing systems use tools such as satellites, sensors, Geographic Information System (GIS), buoys, and acoustic equipment to study large areas of the ocean.
C.6.
The data from these systems can be accessed over the Internet, which allows for remote, real-time exploration of the ocean.
See Principles 1: A
See Principle 3: A11 & A12
See Principle 6: E1
See Principle 6: E6
See Principle 5: B7

Principle 7: The ocean is largely unexplored.

People Explore the Ocean — A	Ocean Exploration Requires Collaboration — B	Ocean Exploration Requires Technological Innovations — C
Exploration leads to a better understanding of systems.	Ocean exploration and the analysis of ocean systems require collaboration and sharing of information on many different levels: local, regional, national, and international.	The ocean has physical properties, such as depth, pressure, light, temperature, and salinity, that make it difficult to explore. Less than 20% of the ocean is mapped, observed, and explored.

A1	B1	B5	B6	C1
There are many opportunities for ocean exploration, which can lead to scientific investigations.	Ocean exploration requires people and organizations in different disciplines of science, technology, engineering, mathematics, and people who carry traditional knowledge, who may be located in different parts of the world, to collaborate and share information.	Local, regional, and national governments play large roles in ocean exploration through regulation and funding.	There are many environmental and community groups that play a role in raising awareness about the importance of ocean exploration.	Exploration of the ocean requires equipment and instruments that can collect data and operate in environments that are vast, have high density, high salinity, extreme temperatures, and increased pressure due to depth.

A2	A5	A6	A7	A8	B2	B3	B4	B4	B4	C2	C3	C4	C5
Ocean explorers are discovering geographic areas, both on the surface and under water, as well as new physical, biological, and geochemical features of the ocean.	Exploration leads to advances in research that will help us better understand changes over time in the climate, the acidification of the ocean, and the health of the ocean.	New methods and technologies are being developed to utilize the ocean for mineral and biological resources, and as a source of energy (e.g., tidal power, wave power, and ocean thermal energy conversion).	New habitats and species continue to be discovered throughout the ocean.	The current exploration of ocean organisms is leading to new discoveries for human health and about our interconnectedness to the ocean.	The communication of accurate and timely information about new discoveries allows the public to make informed decisions that promote sustainability of the ocean.	People build their knowledge and skills in different disciplines, as their careers and/or hobbies. These careers can be in science, engineering, film, photography, architecture, fishing, and boating.	Young people can influence and even participate in ocean exploration by working with scientists and environmental and community groups, by joining online virtual expeditions, and through communication with government officials.	Young people can influence and even participate in ocean exploration by working with scientists and environmental and community groups, by joining online virtual expeditions, and through communication with government officials.	Young people can influence and even participate in ocean exploration by working with scientists and environmental and community groups, by joining online virtual expeditions, and through communication with government officials.	Special equipment has been developed to enable humans to remain below the surface of the ocean for longer periods of time and at greater depths (e.g., wetsuits, SCUBA gear, and human-occupied submersibles).	Submersibles, Remotely Operated Vehicles (ROVs) and Autonomously Operated Vehicles (AUVs), are tools used for prolonged exploration of the ocean.	Acoustic technology, such as sonar, can be used to measure across large distances and to locate unique underwater features.	Ocean-observing systems use tools such as satellites, sensors, Geographic Information System (GIS), buoys, and acoustic equipment to study large areas of the ocean.

A3	A3	A3	A3	A9	A10	C6
Data gathered from advanced technology enables scientists to make better estimations and predictions of physical and biological phenomena.	Data gathered from advanced technology enables scientists to make better estimations and predictions of physical and biological phenomena.	Data gathered from advanced technology enables scientists to make better estimations and predictions of physical and biological phenomena.	Data gathered from advanced technology enables scientists to make better estimations and predictions of physical and biological phenomena.	There are many ways that humans benefit from discoveries about the ocean (e.g., cancer research, new medicines, energy).	There are many ways that human activities negatively impact the ocean that are not fully understood.	The data from these systems can be accessed over the Internet, which allows for remote, real-time exploration of the ocean.

A4	A4	A4	A4
Looking at data over time allows us to better understand the complexity of and changing patterns in the ocean (e.g., noise pollution, weather, sea surface temperatures, and dead zones).	Looking at data over time allows us to better understand the complexity of and changing patterns in the ocean (e.g., noise pollution, weather, sea surface temperatures, and dead zones).	Looking at data over time allows us to better understand the complexity of and changing patterns in the ocean (e.g., noise pollution, weather, sea surface temperatures, and dead zones).	Looking at data over time allows us to better understand the complexity of and changing patterns in the ocean (e.g., noise pollution, weather, sea surface temperatures, and dead zones).