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

All matter on Earth cycles through various reservoirs: the atmosphere, hydrosphere, biosphere, and lithosphere.

Rock Cycle and Plate Tectonics — A

All the rocks on land will end up in the ocean due to weathering and erosion. The continual formation and breakdown of rocks constitutes the rock cycle.

A1

Rocks are constantly being broken down and recycled through weathering, erosion, and processes associated with plate tectonics, such as subduction and uplift.

A2	A3
Many products of weathering and erosion enter the ocean via rivers and atmospheric deposition. All matter remains in the ocean for different lengths of time (residence times).	Oceanic plates are more dense than continental plates and are subducted beneath continental plates when the two collide, causing the continental plates to be lifted.

A4

Subduction can result in the addition of oceanic rocks and sediments to the upper mantle or to the edge of the continent.

A5	A6
Ocean trenches, island arcs, stratovolcanoes, and some mountain ranges are examples of geologic features associated with subduction.	Some parts of the ocean (e.g. the Pacific Rim) are dominated by subducted plate boundaries.

A7

Rocks are constantly being formed through accretion, sedimentation, volcanism, and igneous processes.

A8	A9	A10
Accretion is the process by which material is added to a tectonic plate through subduction and uplift, sea level change, and wave action.	Sedimentation in the ocean can occur by the process of material settling out of the water by gravity so it accumulates on the sea floor, or by the process of currents or waves moving material along the sea floor.	Volcanism at plate boundaries and within plates, as well as uplift and exposure of igneous and sedimentary rocks, creates new rock formations.

Biogeochemical Cycles — B

The ocean plays a major role in the biogeochemical cycles that are fundamental to life on Earth.

B1

All elements are present in ocean water at various concentrations. Many elements in the ocean are needed by all living organisms. These include C, P, N, S, O and many metals such as Fe, Zn, Ca, Na, K. Other elements (Si, Sr) are needed by some select organisms.

Carbon Cycle — B2

The ocean is the largest reservoir of rapidly cycling organic and inorganic carbon on Earth.

B3

Carbon in the form of carbon dioxide in the atmosphere enters the ocean by diffusion, convective mixing, and bubble entrainment. Carbon is present in the ocean in dissolved inorganic (CO_2, H_2CO_3, HCO_3, CO_3, CH_4), organic (carbohydrates, lipids, amino acids), and in particulate forms (carbonate minerals and living and dead organisms).

B4	B7
Inorganic carbon is converted by photo- and chemoautotrophs to organic matter in the process of carbon fixation (e.g., photo- and chemosynthesis.	Inorganic carbon dissolved in seawater is used by some organisms, such as corals, protozoa, and mollusks, to form calcium carbonate ($CaCO_3$) shells and other skeletal parts.

B5	B8
Most of the organic carbon is converted back to inorganic carbon through the process of respiration.	Much of the calcium carbonate from shells dissolves in the deep ocean.

B6	B9
Some organic carbon sinks to the sea floor where it accumulates over time and may become fossil fuel.	Some calcium carbonate from shells and corals accumulates to form sedimentary rocks, i.e., limestone, chalk, and carbonate banks.

B10

Uplift and accretion processes, as well as sea level changes, may relocate sedimentary rocks containing both organic and inorganic carbon onto land, where rocks can undergo weathering and erosion before eventually returning to the ocean.

B11

Anthropogenic burning of fossil fuels converts organic (petroleum) to inorganic carbon (CO_2) and releases carbon back into the atmosphere, which affects the climate and pH balance of ocean water.

Phosphorus Cycle — B12

All life on Earth depends on phosphorus for important compounds, e.g., ATP, DNA, and phospholipids.

B13

Terrestrial weathering of rocks is the primary source of phosphorus (P) in the ocean.

B14

Phosphorus (P) is present in the ocean in dissolved inorganic (HPO_4, PO_4) and organic forms (phospholipids, sugars) as well as in particulate forms (e.g., minerals, such as apatite), and living and dead organisms.

B15

Phytoplankton and other primary producers take up phosphorus dissolved in seawater and convert it to biomass, which is consumed by heterotrophic organisms higher in the food chain. In the process of respiration and regeneration, dissolved and particulate organic phosphorus is converted back to dissolved inorganic forms. Upwelling brings inorganic phosphorus back to the surface.

B16

Some organic (e.g., lipids, sugars) and inorganic (e.g., minerals such as apatite) phosphorus accumulates in ocean sediments, where it undergoes transformations and, over time, becomes part of sedimentary rocks.

B17

Uplift and accretion processes, as well as sea level changes may relocate oceanic sedimentary rocks containing both organic and inorganic phosphorus onto land, where the rocks can undergo weathering and erosion before eventually returning to the ocean.

B18

Anthropogenic loading of phosphorus to waterways, (e.g., rivers, runoff, lakes, and groundwater) from fertilizers and waste water reaches the ocean, where it becomes available to primary producers. Phosphorus may cause eutrophication (i.e., harmful algal blooms) and alter food webs.

Nitrogen Cycle — B19

All life on Earth depends on nitrogen for amino acids and proteins. Most of the nitrogen (N) on Earth is in the atmosphere as N_2, which cannot be used directly by most organisms.

B20

Some bacteria (including some cyanobacteria) in the ocean can fix N_2 in the atmosphere and convert it to organic forms at the cellular level, thus making nitrogen available to other marine organisms.

B21

Nitrogen (N) is continuously transformed between various oxidation states (NO_3, NO_2, NH_4) and compounds (amino acids, urea) in the ocean through biologically-mediated transformation processes, such as nitrogen fixation, nitrification, denitrification, assimilation, ammonification, and anaerobic ammonium oxidation.

B22

Phytoplankton and other primary producers take up nitrogen dissolved in seawater and convert it to biomass, which is consumed by heterotrophic organisms higher in the food chain. In the process of respiration and regeneration, dissolved and particulate organic nitrogen is converted back to dissolved inorganic forms. Upwelling brings inorganic nitrogen back to the surface.

B23

Some organic forms of nitrogen (e.g., lipids, sugars) accumulate in ocean sediments, where they become part of the organic matter in sedimentary rocks.

B24

Uplift and accretion processes, as well as sea level changes may relocate oceanic sedimentary rocks containing nitrogen onto land, where the rocks can undergo weathering and erosion before eventually returning to the ocean.

B25

Anthropogenic loading of nitrogen to waterways (e.g., rivers, runoff, lakes, and groundwater) and the atmosphere from fertilizers, waste water, and fossil fuel combustion, may reach the ocean, where it becomes available to primary producers. Nitrogen may cause eutrophication (i.e., harmful algal blooms) and alter food webs.

Silica Cycle — B26

Some oceanic organisms (e.g., diatoms, radiolarian, sponges) use silica to construct the hard parts of their body, such as tests, frustules, spines, and spicules.

B27

Terrestrial weathering of rocks and volcanic eruptions are the primary sources of silica (Si) in the ocean. Rivers transport the silica weathered from rocks on land to the ocean.

B28

Silica (Si) is present in the ocean in dissolved inorganic (SiO_2) and particulate forms (clays and other materials from land and biogenic skeletal materials).

B29

Most of the biogenic silica skeletal material is dissolved in the ocean after the organisms die, and is converted back to dissolved inorganic silica. Upwelling brings inorganic silica back to the surface.

B30

Some relatively small fractions of the biogenic silica accumulates in ocean sediments, where it undergoes transformations and, over time, becomes part of sedimentary rocks, such as chert, diatomite, and clay materials.

B31

Uplift and accretion processes, as well as sea level changes, may relocate oceanic sedimentary rocks containing silica onto land, where the rocks can undergo weathering and erosion before eventually returning to the ocean.

B32

Anthropogenic activities that alter continental weathering rates (e.g., acid rain) and affect the global water cycle may change the flux of silica into the ocean.