CARBON CYCLE GAME

This lesson plan developed by:

RUTGERS
THE STATE UNIVERSITY
OF NEW JERSEY

Overview:

Introduce students to the importance of carbon and its cycling between the living and nonliving parts of the ecosystem and the earth system.

Key Concepts:

- Model the movement of carbon through different reservoirs
- Compare and contrast fast and slow processes (short and long residence times) that move carbon
- Understand that the path taken by an atom through a biogeochemical cycle is complex, not a circle, and provide an example of conservation of matter
- Put processes such as photosynthesis and respiration in the larger context of biogeochemical cycling

Materials:

- Carbon Cycle Game Dice
- Scissors
- Scrap paper
- Tape
- String or lanyard (8 inches per student)
- Pony beads (white, light blue, dark blue, light green, pink, dark green, orange, purple, grey and brown) need the 10 distinct colors
- 10 cups (one for each station)
- Carbon Reservoir Station Markers (atmosphere, surface ocean, ocean plants etc.)
- Carbon Cycle Game Worksheet (one per student)
- Pencils or pens
- Unopened, undisturbed bottle of seltzer or clear soda (optional)

Carbon Cycle Game (cont.)

Set-up Prior to Activity:

1. Print out the Carbon Cycle Game Dice. It is helpful, but not necessary to have more than one die for each station.
2. Cut out the dice and crease along the lines between the faces.
3. Tape the open edges together to make a cube. It is helpful to weight the dice with a ball of scrap paper about the same size as the finished cube. Filled dice roll more easily than empty ones.
4. Print out the Station Markers.
5. Set up each station in a different location around the room. Each station should have:
    a. At least one die. (Duplicates are especially helpful for the Atmosphere and Surface Ocean stations; students will visit these often, and not having to wait in line to roll dice will make gameplay faster.)
    b. A station marker posted where students can easily see it once moving around the room.
    c. A cup filled with the corresponding color of beads.
6. Cut lengths of string or lanyard (~8 inches) for each student and knot one end.

Duration:

45 minutes

Physical Activity:

Moderate

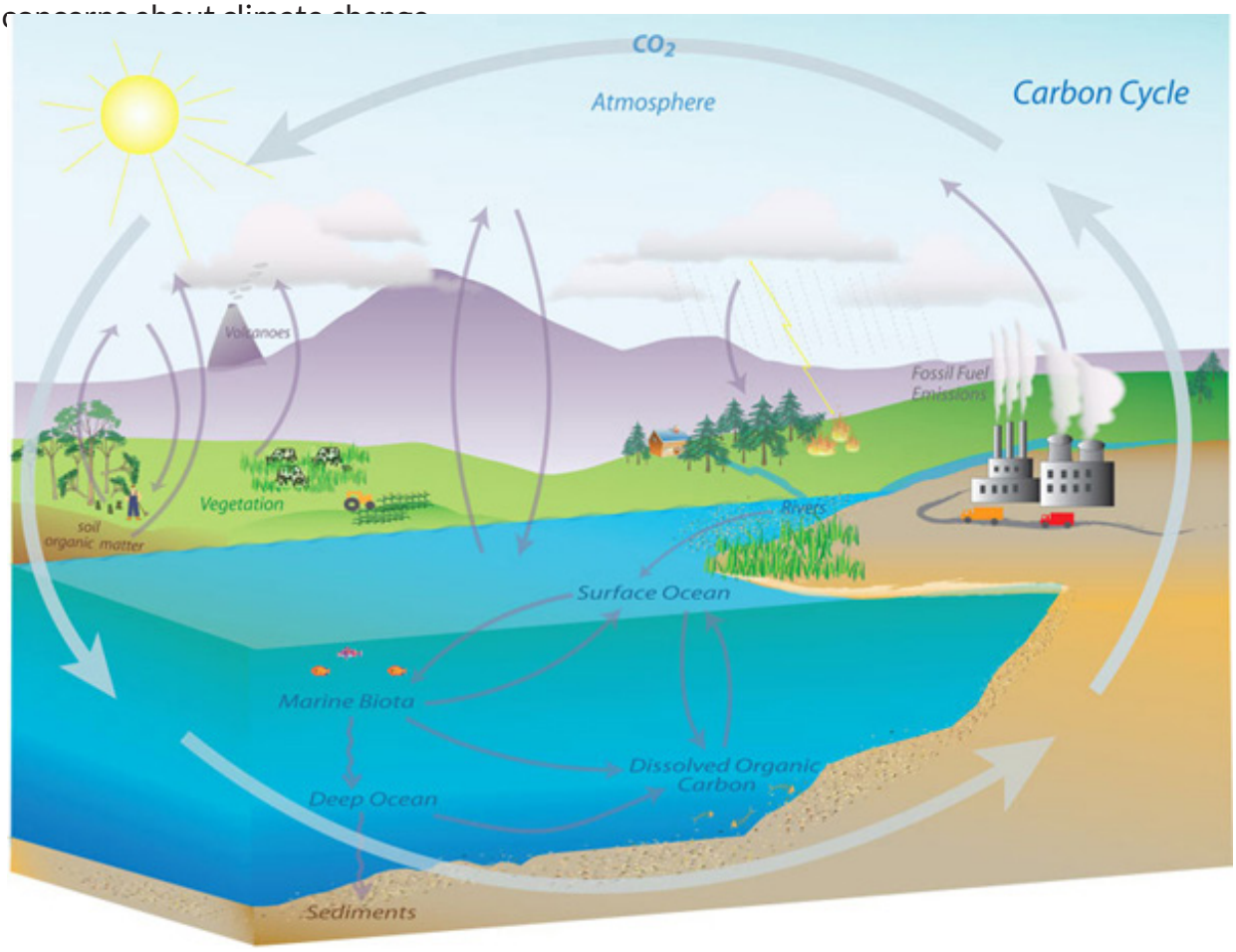
Background:

Students will take on the role of a carbon atom and record which reservoirs in the carbon cycle they visit. They will compare and contrast their trip with those of their classmates to discover information about sources and sinks, and residence times of the different reservoirs. Ocean processes are highlighted to allow the educator to define the biological pump and explain its importance to climate.

Understanding the sources and sinks of atmospheric carbon dioxide is necessary to understanding the causes and consequences of climate change. The carbon cycle is complex, with many reservoirs both living and nonliving, each with a number of sources and sinks. To put the carbon cycle in the context of understanding climate change and the issues scientists are concerned with, we focus on the sinks of atmospheric carbon dioxide, and the fate of the carbon after it is removed from the atmosphere. As people burn fossil fuels for energy, large amounts of carbon dioxide are released into the atmosphere. This introduces a large source of both carbon, and a greenhouse gas. Scientists interested in the long term effects and possible outcomes of this source of greenhouse gas are interested in sinks that not only remove carbon dioxide from the atmosphere, but provide a source of carbon to a reservoir with a long residence time.

Carbon Cycle Game (cont.)

Understanding the connections between reservoirs, and the interaction between long and short residence times, is very helpful in understanding ongoing scientific research and its importance to concerns about climate change.



Activity:

1. Review with the students why carbon is so important (to biology, and climate)
2. Tell students they are going to be a carbon atom moving through the carbon cycle. Review the water cycle as a familiar concept, and introduce terms such as reservoir, source and sink using the water cycle as an example.
3. Go over what reservoirs will be included in the carbon cycle game. Note for students that there are many other reservoirs we are not including, such as fossil fuels.
4. Review the rules of the game:
    a. Students will keep track of their journey by adding a bead to their string to represent each reservoir they visit.
    b. Students should add a bead first, so they don't forget, then roll the dice.
    c. Students should read the dice carefully for information about the process that is moving them from one reservoir to another, and then go to their next station as

instructed by the dice.
   d. If a die tells them to stay in place for a turn, they should add another bead of that color before re-rolling.
   c. As students represent carbon, an element, they don't "want" to go to any particular place. There is no "goal" they are trying to get to and they should go where the dice take them. Each turn they should roll the appropriate die ONCE, and whatever it says is what they do.
   e. Students should continue moving through the cycle until they have fifteen beads on their string.
5. Give students their starting location. The carbon cycle is a large and complex topic, so how you distribute them is up to whatever connections you would like to make during the discussion portion.
   a. If you would primarily like to discuss residence time, start a couple groups of students in the atmosphere and surface ocean, and a couple in sediments and deep ocean dissolved reservoirs. This is where it is helpful to have duplicate dice for some stations – if you would like eight students to start in the atmosphere, you may want to make at least eight atmosphere dice.
   b. For the biological pump, start all students in the atmosphere and surface ocean. Be sure you don't let any students begin in the deep ocean particles or ocean sediments.
   c. Once students get the hang of it, the game goes quickly, so if you have enough materials you can certainly run the game more than once, with a slightly different focus each time.
6. Monitor students as they move through the cycle and remind them of the rules if needed
7. When students have finished their cycle, pass out worksheets and have them decode their string of beads back to which reservoirs they represent.

Discussion:

1. Have students compare their cycle to their neighbors'.
2. Use the diagram in the background to represent the journey through the cycle as a series of arrows. Is a cycle a circle?
3. Discuss the journeys students took. Possible discussion topics include:
   a. Overall, which reservoirs did students visit most?
   b. Which reservoirs have long residence times? Which have short residence times?
   c. What are the processes that move carbon from one reservoir to another? (Choose a few to highlight.) Use the seltzer or soda to discuss carbon dioxide moving between air and water. Initially many students will use the terms "evaporation" and "condensation" when you ask them how carbon moves from one to the other; remind them that those are terms for the water cycle and for changes in state of matter. The soda is helpful both to show that air and gas dissolves in water in the same way that solutes such as salt do, and help them connect to the short residence time of gas in a liquid ("If I open this and leave it hear overnight, will it still be fizzy

tomorrow?").

d. What processes move carbon from the atmosphere to the ocean sediments? Define the biological pump for students. The biological pump is the set of processes in the ocean that sequester carbon (make it unavailable to be recycled back into the atmosphere for a long period of time). Identify if any students were sequestered (Atmosphere – Surface Ocean – Ocean Plants – Deep Particles – Ocean Sediments. Can also stop at Ocean consumers between plants are particles). Scientists are interested in areas of the ocean with a very efficient biological pump, as well as areas of the ocean where the biological pump is either less efficient than expected, or decreasing in efficiency.
e. Have students brainstorm what reservoirs and processes have not been included in the game (soils, fossil fuels, sedimentary rocks; burning of fossil fuels, subduction of sediment and volcanic eruptions for a few examples).

Ocean Literacy Principles:

Ocean literacy is an understanding of the ocean's influence on us, and our impact on the ocean. There are seven Ocean Literacy Essential Principles that all people of our blue planet should have an opportunity to learn and understand. This activity touches upon the following Essential Principles:

1. The Earth has one big ocean with many features
2. The ocean and life in the ocean shape the features of Earth
3. The ocean is a major influence on weather and climate
4. The ocean made the Earth habitable
5. The ocean supports a great diversity of life and ecosystems
6. The ocean and humans are inextricably interconnected
7. The ocean is largely unexplored

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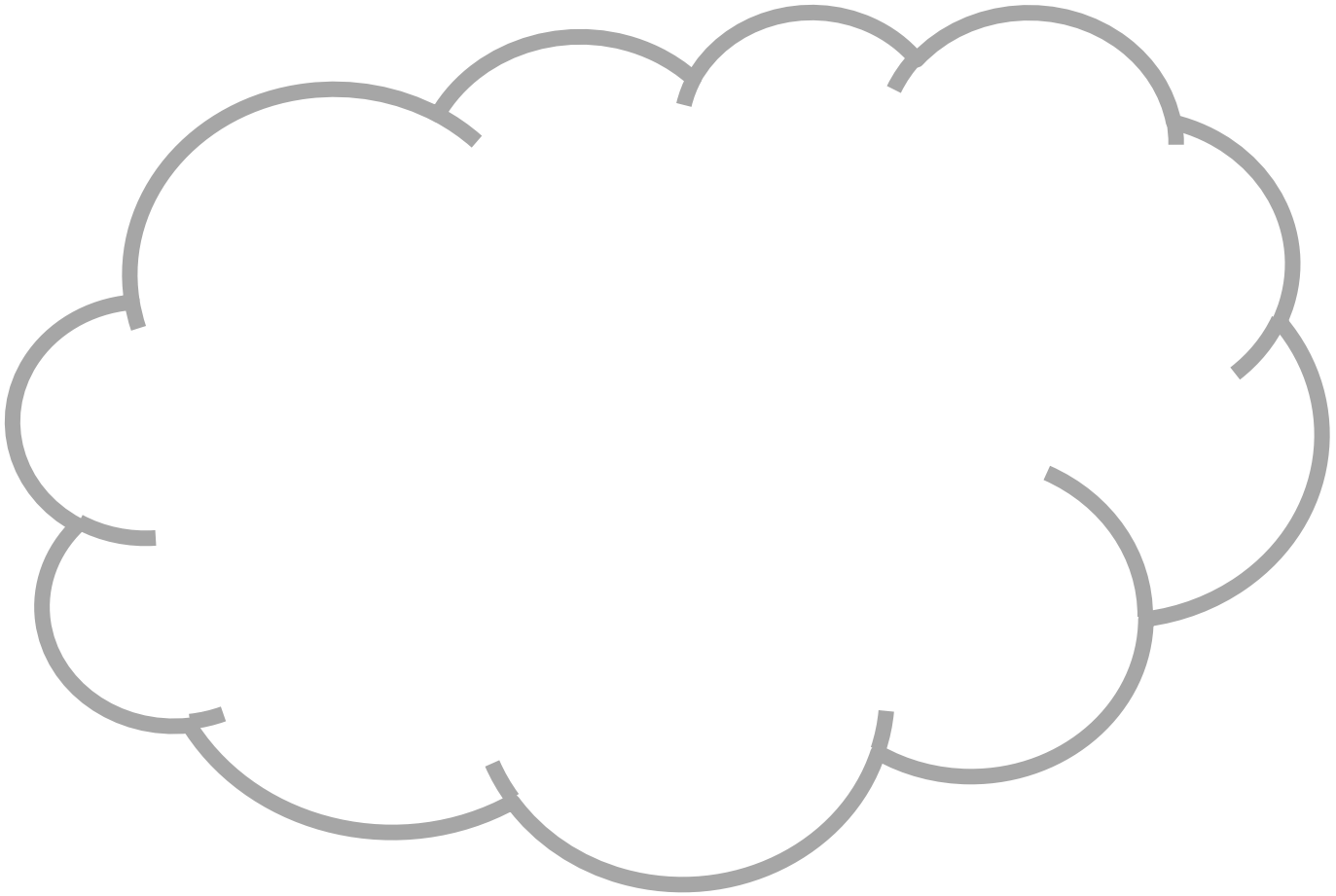
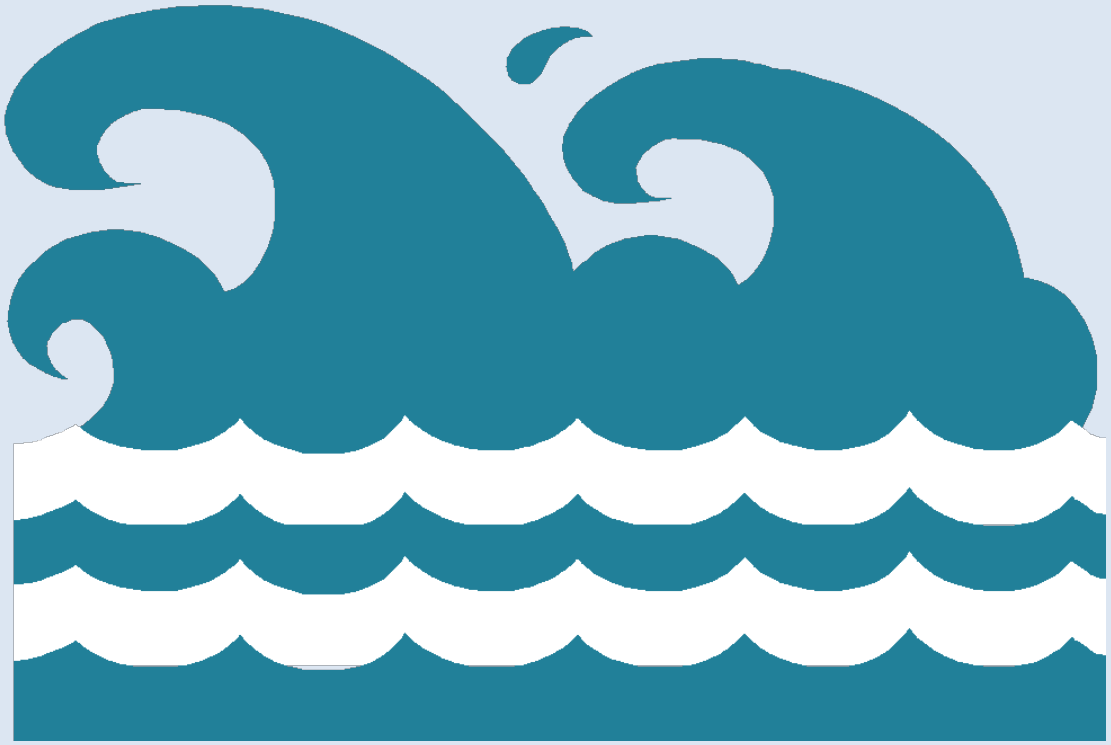
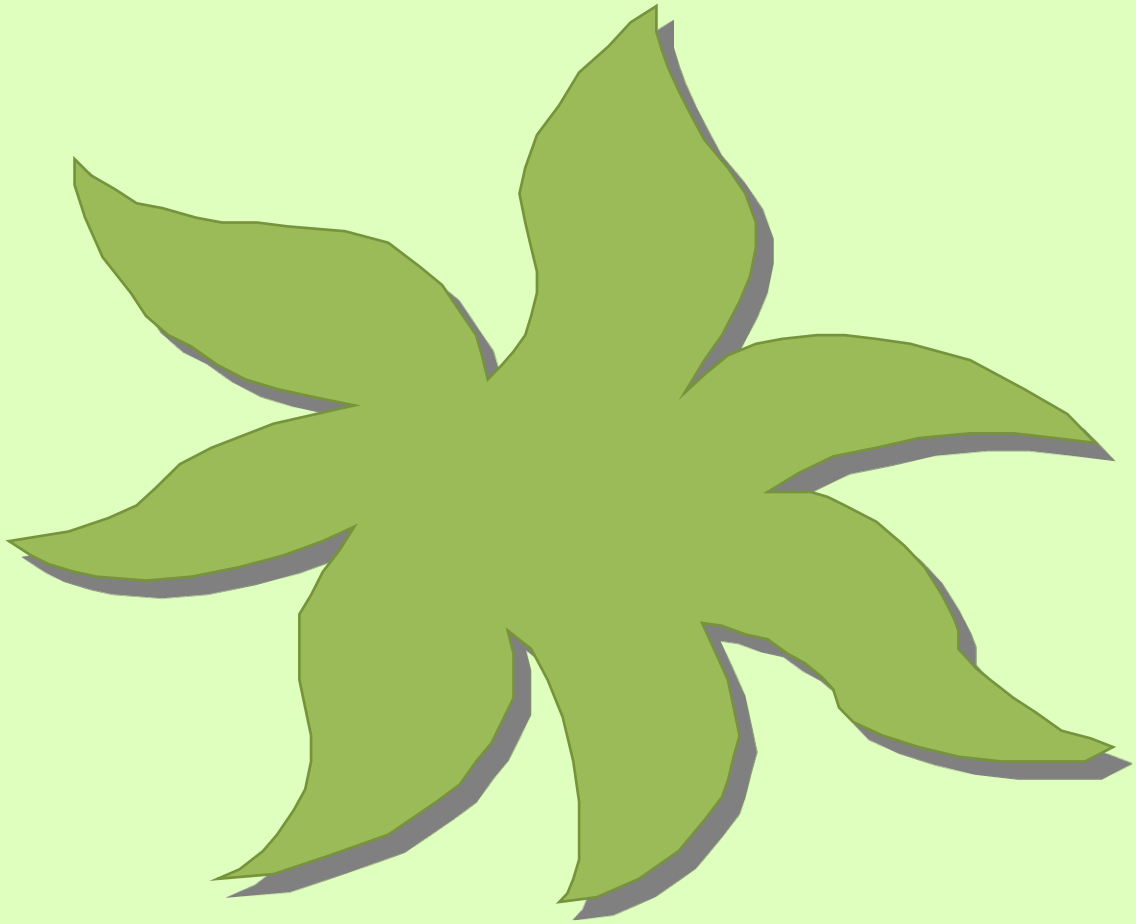
ATMOSPHERE



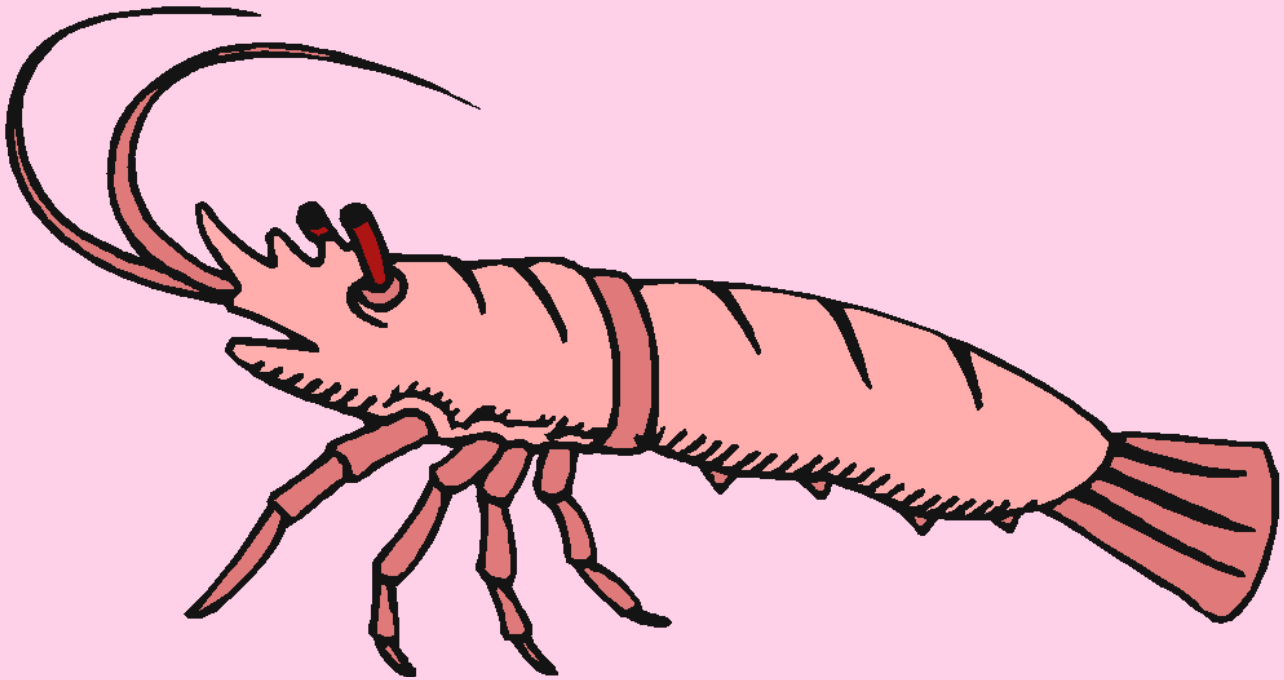
SURFACE OCEAN



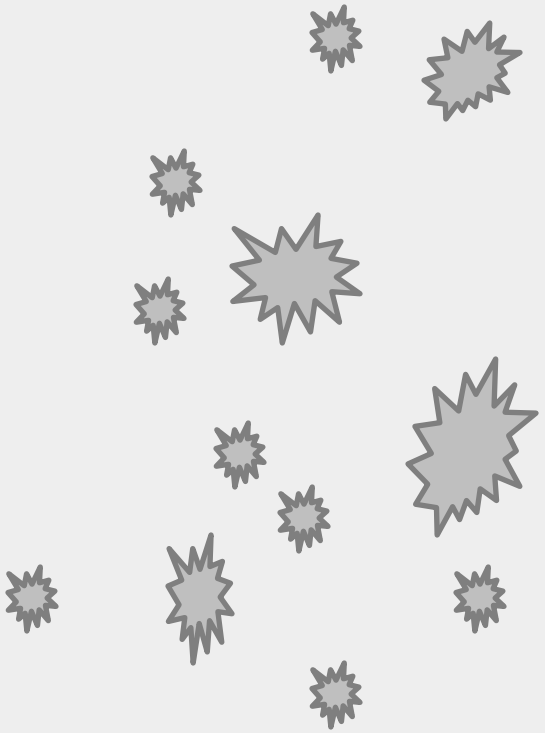
OCEAN PLANTS



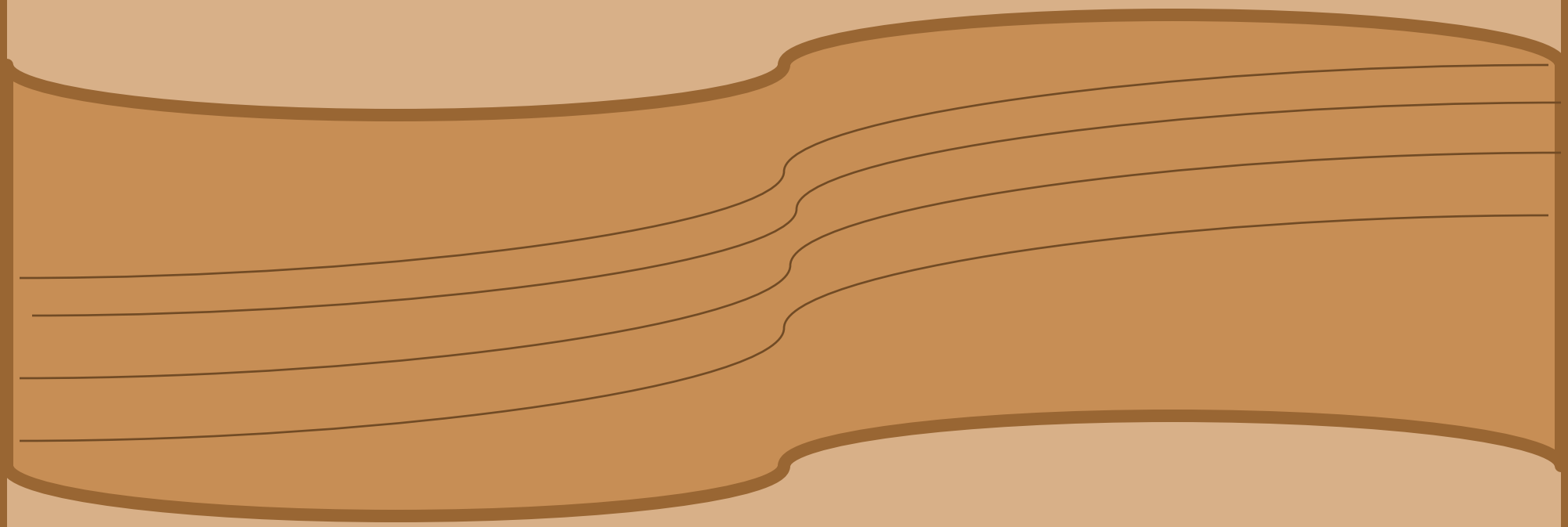
OCEAN CONSUMERS



DEEP PARTICLES

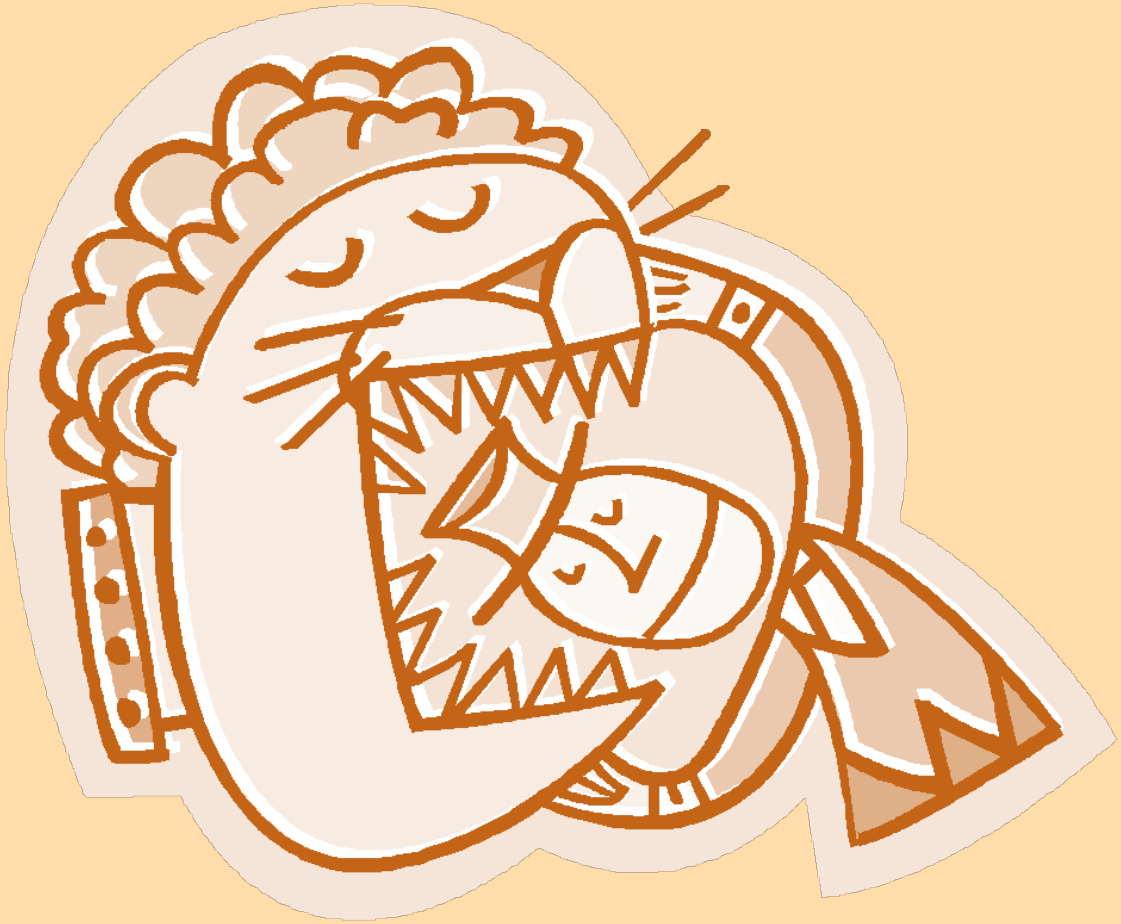


OCEAN SEDIMENTS

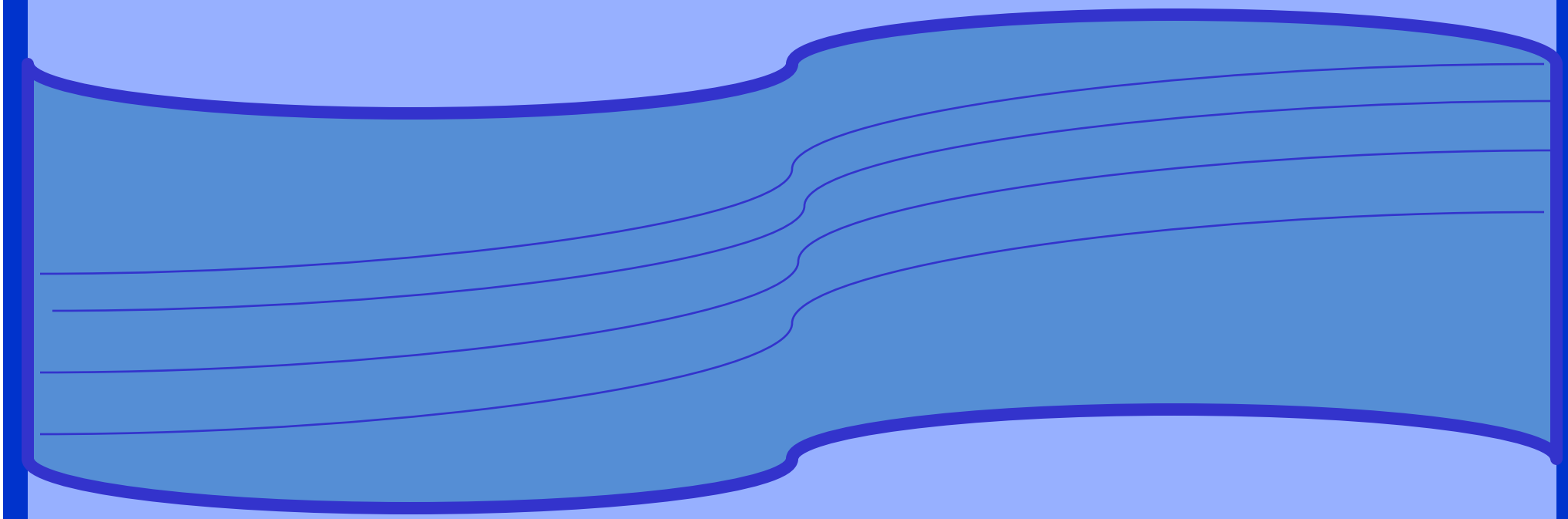


LAND PLANTS

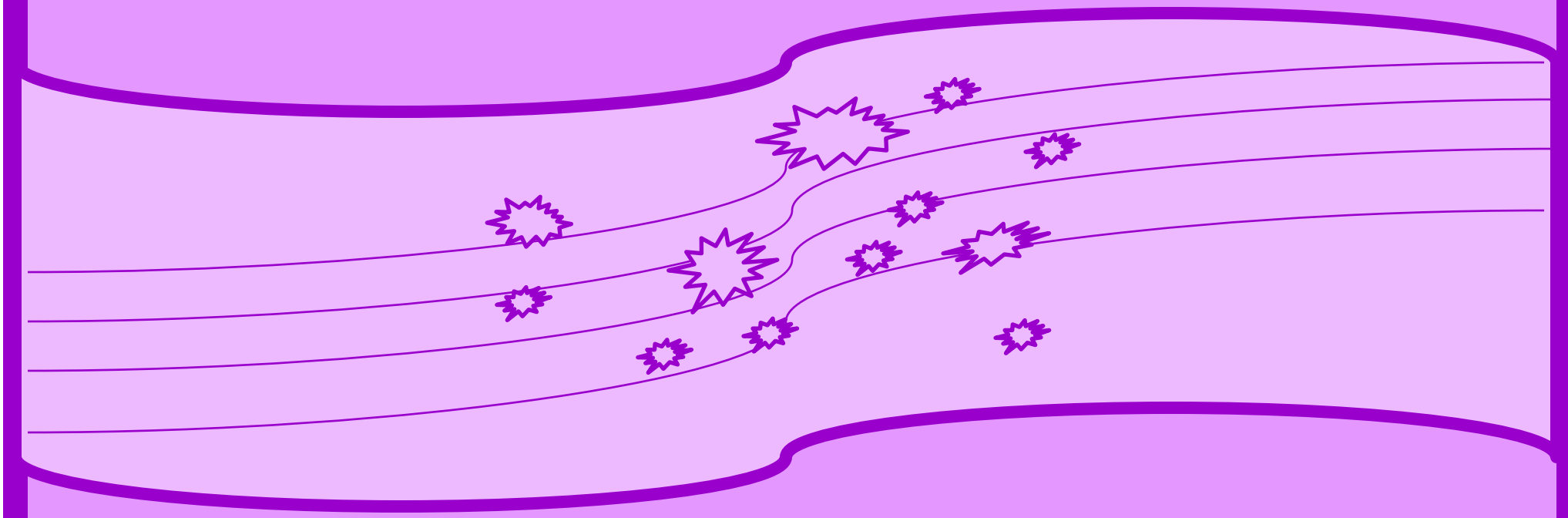
LAND CONSUMERS



FRESH WATER



DEEP DISSOLVED



ATMOSPHERE dice
(white)

LAND PLANTS

You are carbon in the form of CO_2.
You are taken up by the plant for photosynthesis.

Go to LAND PLANTS.

FRESH WATER

You are carbon in the form of CO_2.
You dissolve in water.

Go to FRESH WATER.

SURFACE OCEAN

You are carbon in the form of CO_2.
You dissolve in water.

Go to SURFACE OCEAN.

SURFACE OCEAN

You are carbon in the form of CO_2.
You dissolve in water.

Go to SURFACE OCEAN.

ATMOSPHERE

You are carbon in the form of CO_2.
You stay in the atmosphere.

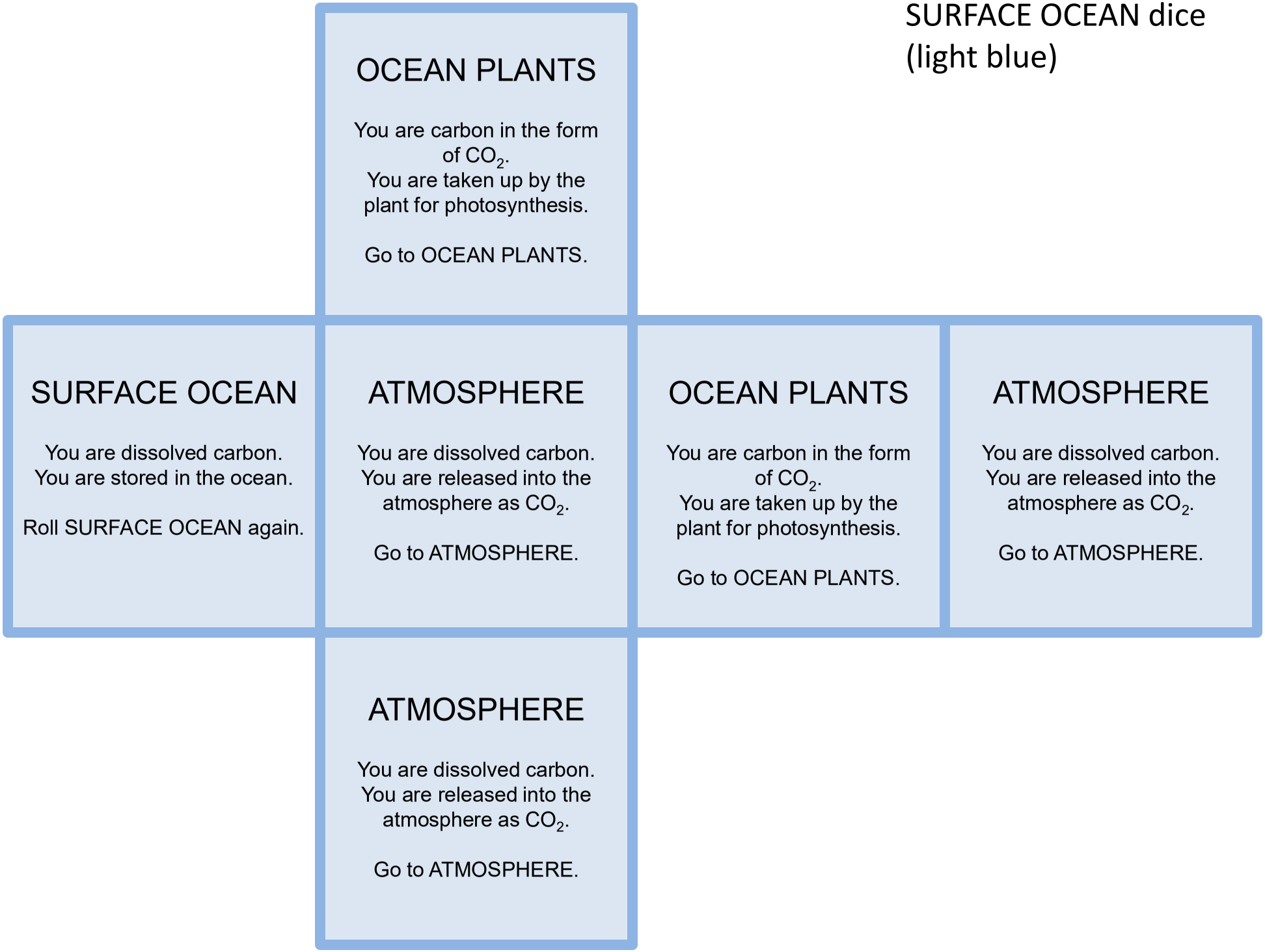
Roll ATMOSPHERE again.

SURFACE OCEAN

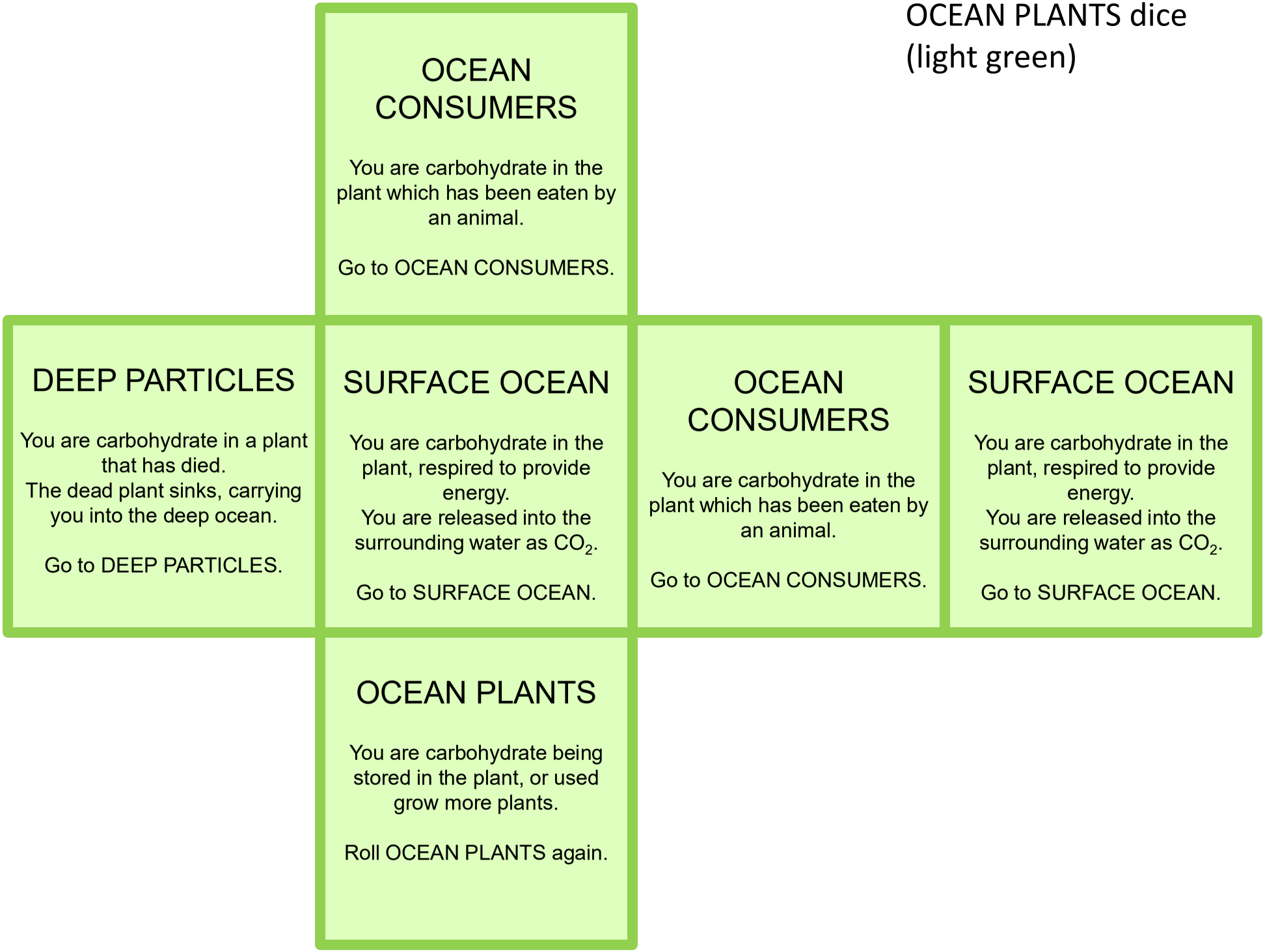
You are carbon in the form of CO_2.
You dissolve in water.

Go to SURFACE OCEAN.

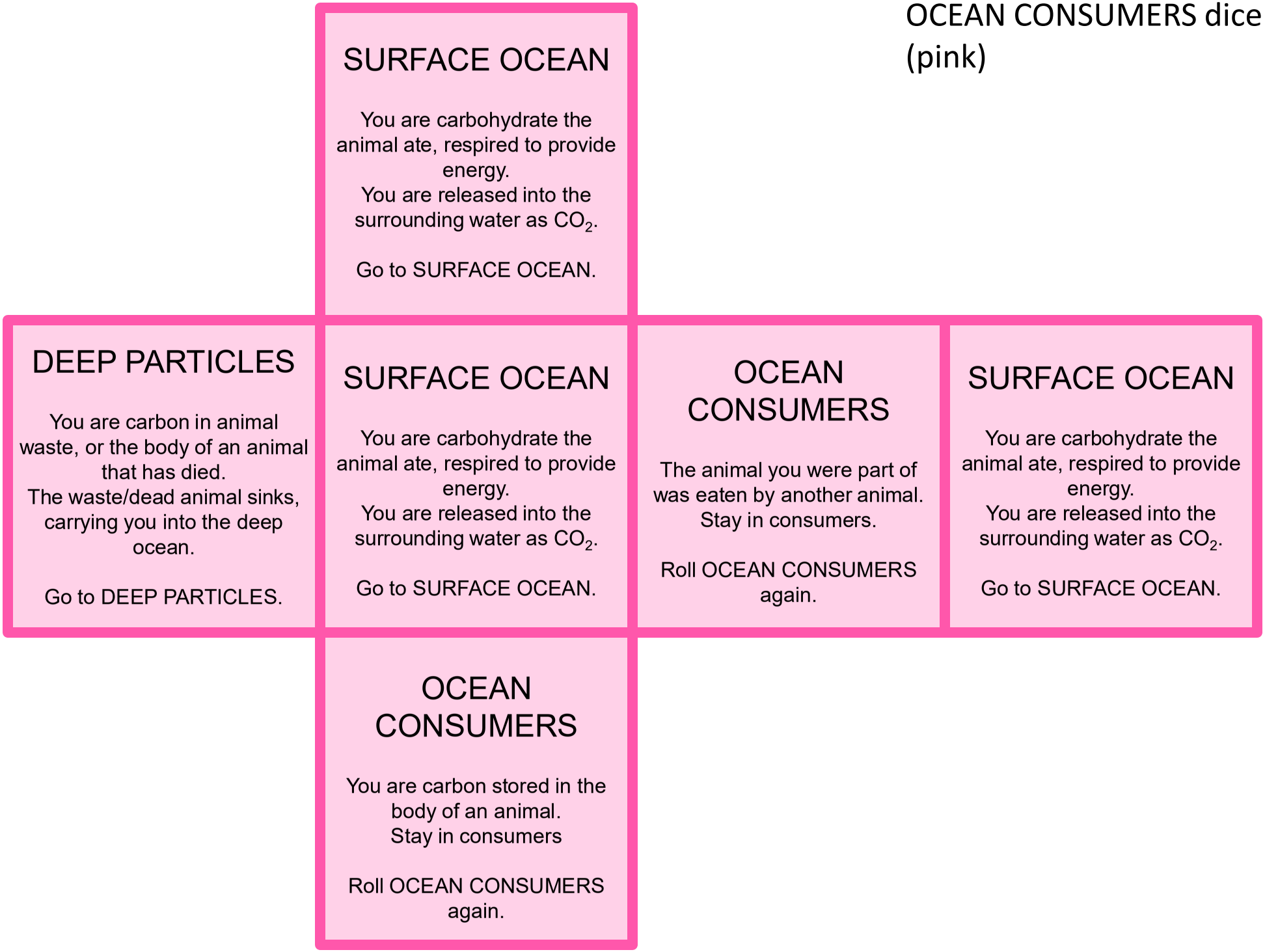
SURFACE OCEAN dice
(light blue)



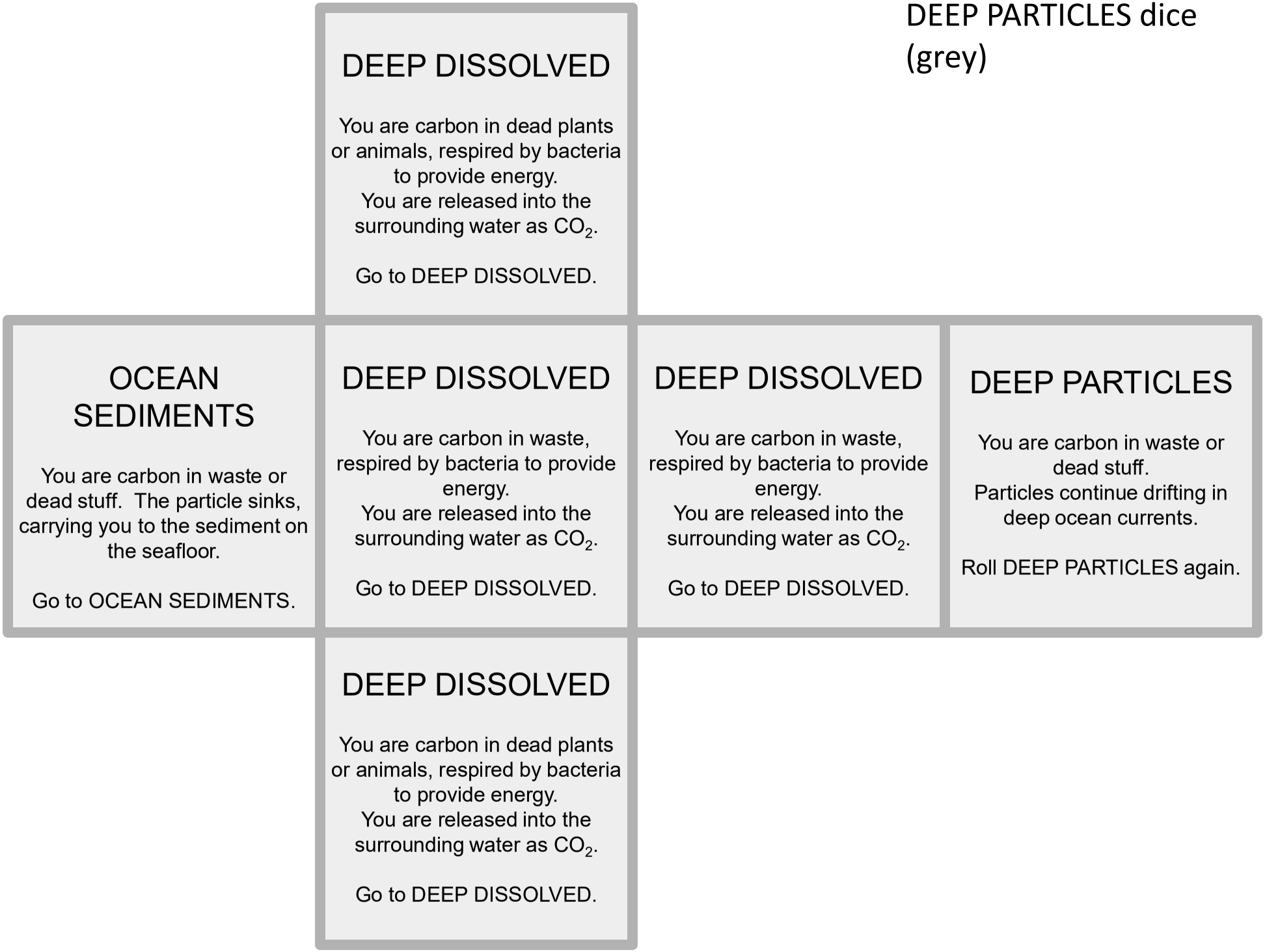
OCEAN PLANTS dice
(light green)



OCEAN CONSUMERS dice (pink)



DEEP PARTICLES dice (grey)



OCEAN SEDIMENTS dice (brown)

OCEAN SEDIMENTS

You are carbon in dead plants and animals.
You are covered by sediments and buried.

Roll OCEAN SEDIMENTS again.

OCEAN SEDIMENTS

You are carbon in dead plants and animals.
You are covered by sediments and buried.

Roll OCEAN SEDIMENTS again.

OCEAN SEDIMENTS

You are carbon in dead plants and animals.
You are covered by sediments and buried.

Roll OCEAN SEDIMENTS again.

OCEAN SEDIMENTS

You are carbon in dead plants and animals.
You are covered by sediments and buried.

Roll OCEAN SEDIMENTS again.

OCEAN SEDIMENTS

You are carbon in dead plants and animals.
You are covered by sediments and buried.

Roll OCEAN SEDIMENTS again.

DEEP DISSOLVED

You are carbon in the top layer of the sediments.
You are respired by bacteria to provide energy and released into the surrounding water as CO_2.

Go to DEEP DISSOLVED.

LAND PLANTS dice
(dark green)

LAND PLANTS

You are carbohydrate being stored in the plant, or used grow more plants.

Roll LAND PLANTS again.

FRESH WATER

You are in plant matter that has washed into a stream or lake.

Go to FRESH WATER.

ATMOSPHERE

You are carbohydrate in the plant, respired to provide energy.
You are released into atmosphere as CO_2.

Go to ATMOSPHERE.

LAND CONSUMERS

You are carbohydrate in the plant which has been eaten by an animal.

Go to LAND CONSUMERS.

ATMOSPHERE

You are carbohydrate in the plant, respired to provide energy.
You are released into atmosphere as CO_2.

Go to ATMOSPHERE.

LAND CONSUMERS

You are carbohydrate in the plant which has been eaten by an animal.

Go to LAND CONSUMERS.

LAND CONSUMERS dice (orange)

ATMOSPHERE

You are carbohydrate the animal ate, respired to provide energy.
You are released into the atmosphere as CO_2.

Go to ATMOSPHERE.

ATMOSPHERE

You are carbohydrate the animal ate, respired to provide energy.
You are released into the atmosphere as CO_2.

Go to ATMOSPHERE.

ATMOSPHERE

You are carbohydrate the animal ate, respired to provide energy.
You are released into the atmosphere as CO_2.

Go to ATMOSPHERE.

FRESH WATER

You are carbon in animal waste that has washed into a stream or lake.

Go to FRESH WATER.

LAND CONSUMERS

The animal you were part of was eaten by another animal.
Stay in consumers.

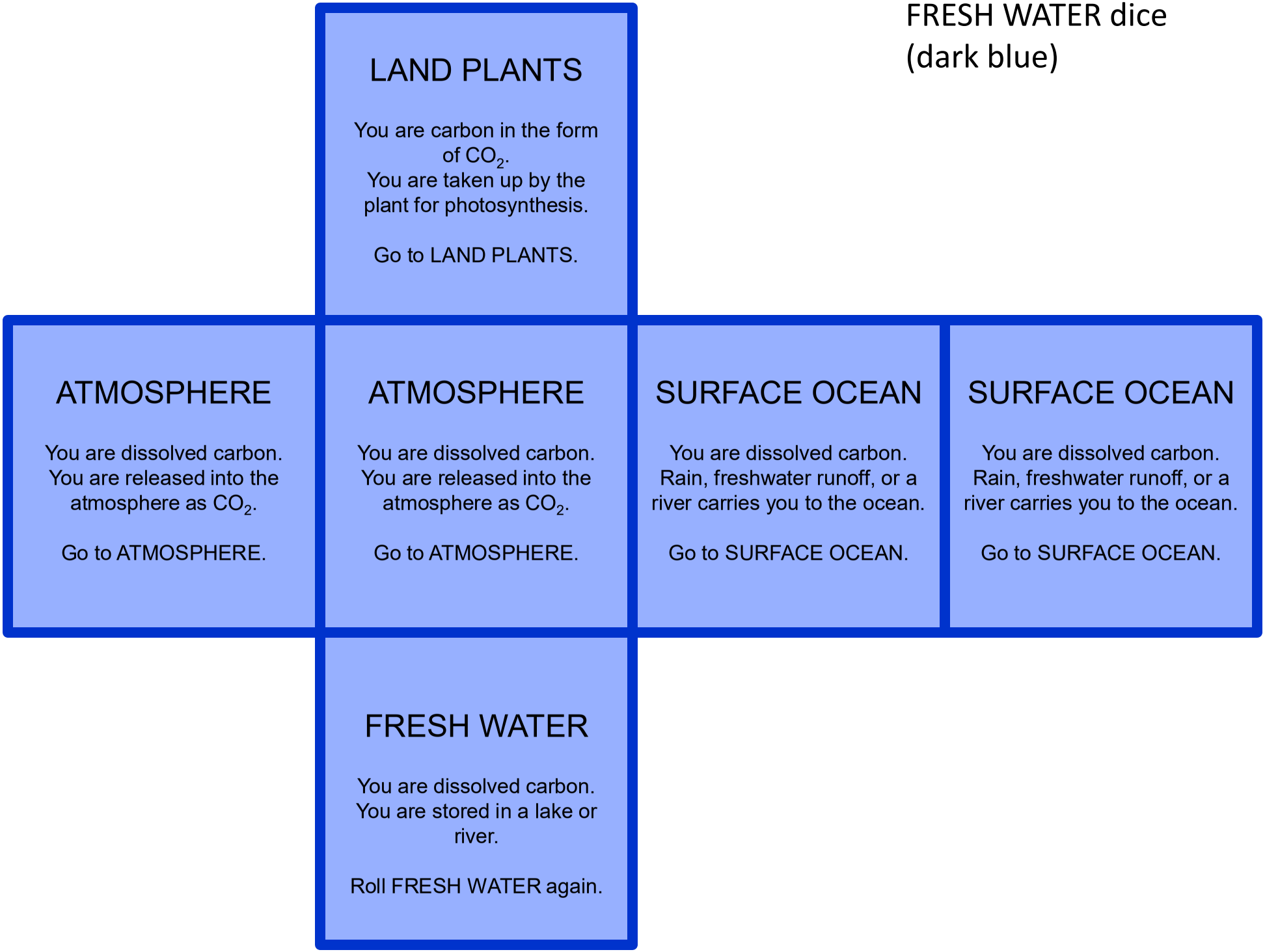
Roll LAND CONSUMERS again.

LAND CONSUMERS

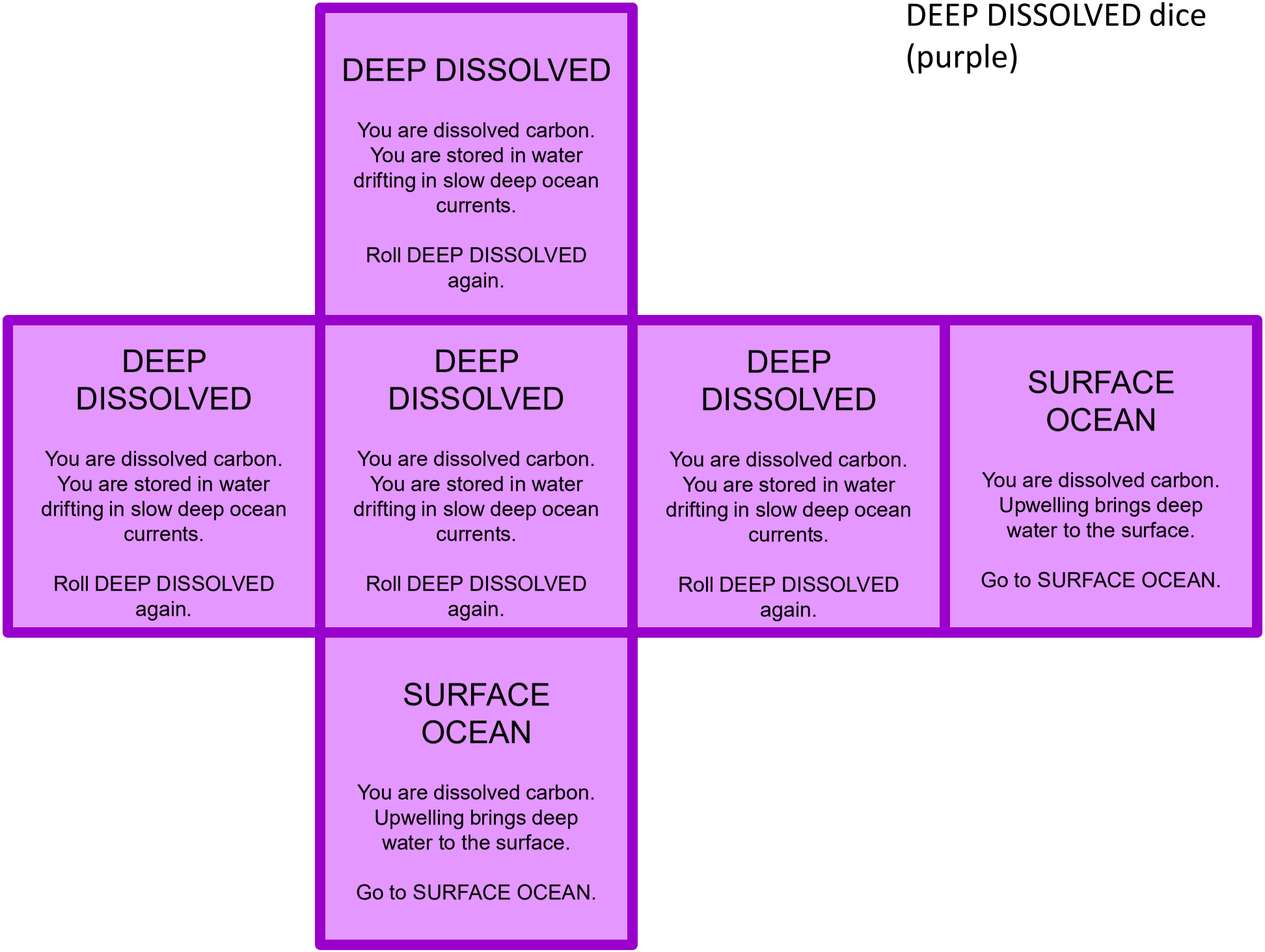
You are carbon stored in the body of an animal.
Stay in consumers

Roll LAND CONSUMERS again.

FRESH WATER dice
(dark blue)



DEEP DISSOLVED dice (purple)



Carbon Cycle Game (cont.)

Record your journey as you move through the stations. Where did your carbon atom go?

Carbon pool

1. _____
2. _____
3. _____
4. _____
5. _____
6. _____
7. _____
8. _____
9. _____
10. _____
11. _____
12. _____
13. _____
14. _____
15. _____

Questions:

Where did you spend the most time? (which carbon pool?)

Compare your carbon atom's path with your neighbor's. Did you take the same path? Did you go the same places?

Carbon Cycle Game (cont.)

Where did your carbon atom go? (use your Key to decode your bracelet)

	Bead color	Carbon pool
1.	_____	_____
2.	_____	_____
3.	_____	_____
4.	_____	_____
5.	_____	_____
6.	_____	_____
7.	_____	_____
8.	_____	_____
9.	_____	_____
10.	_____	_____
11.	_____	_____
12.	_____	_____
13.	_____	_____
14.	_____	_____
15.	_____	_____

KEY:

White = ATMOSPHERE
Light blue = SURFACE OCEAN
Light green = OCEAN PLANTS
Pink = OCEAN CONSUMERS
Dark blue = FRESH WATER
Dark green = LAND PLANTS
Orange = LAND CONSUMERS
Gray = DEEP OCEAN, PARTICLES
Purple = DEEP OCEAN, DISSOLVED
Brown = OCEAN SEDIMENTS

Questions:

Where did you spend the most time? (which carbon pool?)

Compare your carbon atom's path with your neighbor's. Did you take the same path? Did you go the same places?