LESSON A4
CARBON CYCLE: LAND IS PART OF THE CLIMATE SYSTEM

MAIN SUBJECTS
Natural sciences / Physics / Chemistry

DURATION
~ Preparation: 15 min
~ Activity: 1h15

AGE GROUP
12-15 years

LEARNING OUTCOMES
While playing a board game about the carbon cycle, students will learn that:
~ Carbon circulates in the carbon cycle and that human activities disturb it.
~ Soil is an important carbon reservoir.
~ Fossil fuels are important underground reservoirs.
~ Fossil fuels need a lot of time to be formed (several millions of years).
~ Their use releases CO_2, previously stored in the soil, into the atmosphere.
~ Through photosynthesis, plants capture CO_2 from the atmosphere and store it in organic matter.
~ Through fermentation, respiration and decomposition of organic matter, land vegetation releases CO_2 into the atmosphere.
~ Vegetation and land play a key role in the carbon cycle.

KEYWORDS
Carbon, CO_2, photosynthesis, biosphere, respiration, erosion, combustion, sedimentation, outgassing, dissolution

TEACHING METHOD
Board game and / or multimedia animations

PREPARATION 15 MIN

EQUIPMENT

TEACHER TIP
This activity can be carried out using either multimedia animation or the role-play card game, or both of them.

- 69 plastic tokens representing carbon – you may also use small pieces of cardboard (for each group of 5 students).
- One triangle-shaped small piece of paper (0.5 cm each side) that will be used as a cursor to mark the temperature (for each group).

TEACHER TIP
The tokens should be light and small enough to be easily moved across the board. You can choose different sizes and shapes to represent 5 and 10 carbon atoms, and smaller ones to represent 1 atom of carbon.
Here is an example:

- **WORKSHEET A4.1**.
- Gameboard: **WORKSHEET A4.2** (one for each group—you can laminate it in order to reuse it), preferably on an A3 sheet
- **WORKSHEET A4.2** may also be printed in small versions (2 copies on one page) to be used during wrap-up.
- Carbon cycle play cards (one batch per group): **WORKSHEETS A4.3** to **A4.4**.
  Note: WORKSHEETS A4.4 are only needed for the second part of this lesson.
- Optional: Computers / tablets (at least one for each pair of students) to use the Multimedia resource "Carbon cycle".

LESSON PREPARATION

1. Gather 69 tokens for each group.
2. Print **WORKSHEET A4.2**, preferably on an A3 sheet – it will be used as a board for the game.
3. Print **WORKSHEET A4.2** in small versions, one for each student.
4. Print **WORKSHEETS A4.3** and **A4.4**. You can print them double-sided. We suggest laminating the cards in order to reuse them. Put aside the cards from **WORKSHEET A4.4** (they will be used in Part 2) and shuffle all the others.
5. Divide students evenly into groups of 5 or 6. Each group will have its own board, set of cards and tokens.

INTRODUCTION 15 MIN

Before starting this activity, ask your students to recall what they learned from the previous lesson – that current anthropogenic greenhouse gas emission is responsible for climate change and that global CO_2 emissions have increased since the Industrial Revolution (you can use the second graph on **WORKSHEET A3.2**).

Conduct a classroom discussion:

- *How do you think this situation will evolve over the next decades?* (carbon dioxide emissions will probably increase)
- *How do you think we could limit this increase?*
- *Do you know any natural processes that are part of / that influence the carbon cycle?* List them on the board.

In order to learn more about these processes, the students will have to investigate where they can find carbon on Earth. For this, they must study the carbon cycle to understand how carbon flows from one place to another on Earth, and that it does not disappear but is being exchanged between different types of storage. To do so, explain that they will play a board game about the carbon cycle.

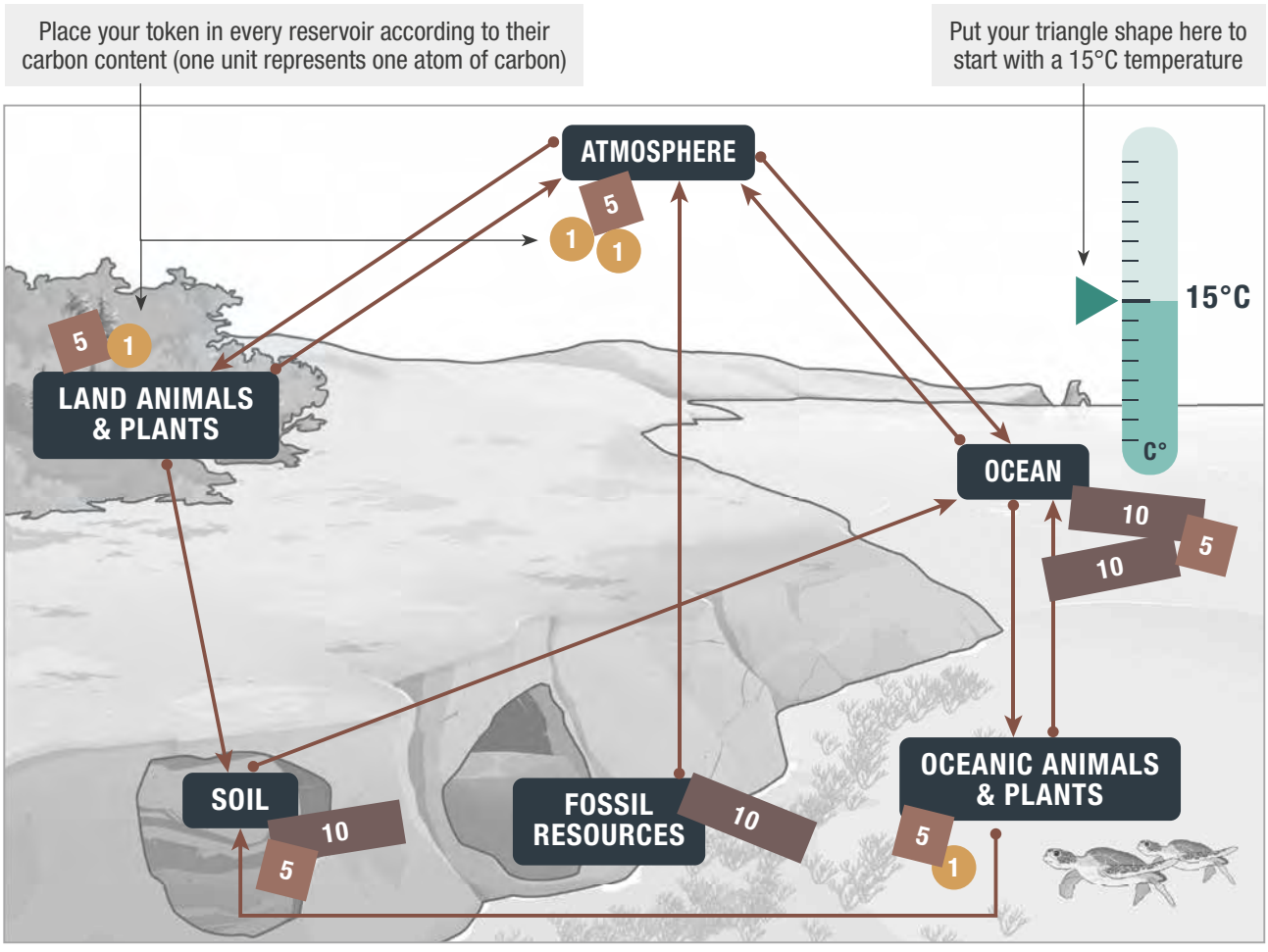
Discuss how carbon is a common element on earth. Have students recall some of the things or living beings in their daily lives that they think contain carbon. Make a list of these items on the board.

Explain that the carbon contained in any one thing does not stay there forever. The carbon atoms move from one thing to another in what is called **the carbon cycle**. Some parts of the carbon cycle happen very quickly, as when plants absorb carbon dioxide from the atmosphere for photosynthesis. However, some other parts of the carbon cycle proceed very slowly, like the conversion of carbon-containing organic matter to fossil fuels.

PROCEDURE 50 MIN

PART 1: THE NATURAL CARBON CYCLE 30 MIN

1. Explain to your students that the tokens represent the carbon that can be found on Earth and that this carbon is stored in what we call “reservoirs”. There are 6 major reservoirs on Earth: atmosphere, ocean, aquatic organisms, terrestrial organisms, soil and fossil fuels. Write these words on the board.



The gameboard at the starting point.

2. Divide students evenly into groups. Give each group a board (**WORKSHEET A4.2**), a batch of tokens, and the triangular cursor – they will have to place it in the middle of the thermometer so they start with a 15°C temperature (see the diagram before).

3. Show the table in **WORKSHEET A4.1**: the students will have to put the correct number of tokens on each reservoir. Point out that the reservoirs on land are diverse and contain much carbon.

4. Explain that they will have to make their carbon move, mimicking some natural phenomenon. Distribute the "Natural cycle" cards **(WORKSHEETS A4.3 only)**: they will have to flip cards one by one and move a token according to the description on the card. Each time they add a token to the atmosphere, they will have to make the temperature rise using the triangular cursor; each time they remove a token from the atmosphere, the temperature will decrease.

5. Once the stack of cards is empty, ask: *How many tokens are now left in each reservoir? Are there as many as at the beginning? How has the temperature changed? How can you explain this?* At the end of the game there should be the same number of tokens in each reservoir as at the beginning because students can only move tokens around, rather than removing them. Explain that in this way **the cycle is perfectly balanced**. Point out that carbon only flows from one reservoir to another but never disappears and that some processes allow carbon to be "extracted" from the atmosphere. This is the reason why the temperature is still 15°C at the end of the natural cycle.

TEACHER TIP

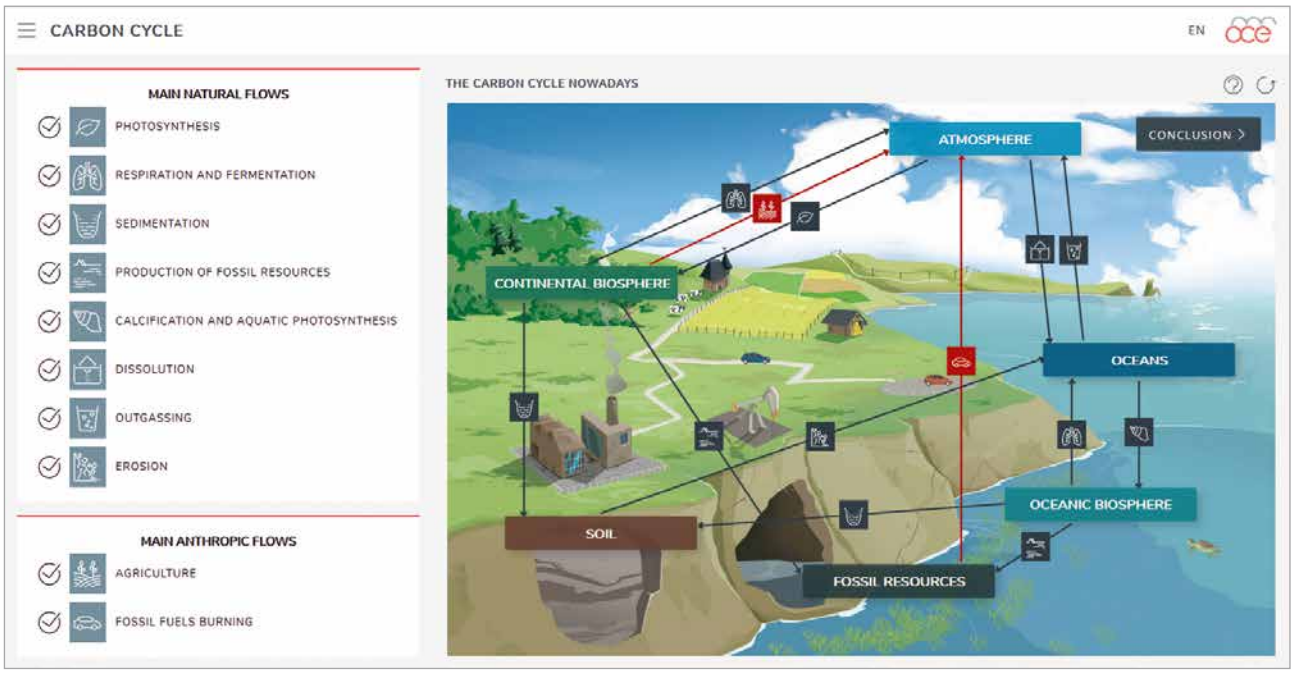
For more advanced students, you can also discuss the speed of these processes, represented here by the number of cards: for example, the carbon moves associated with photosynthesis or respiration are much faster than sedimentation (there are more cards for these).

PART 2: HUMAN IMPACTS ON THE CARBON CYCLE 20 MIN

6. Explain to your students that they have just performed the carbon cycle **without human intervention,** but that humans greatly influence this carbon cycle with some of their activities.

7. Distribute the "human activities" deck of cards (**WORKSHEETS A4.4**) and ask the students to shuffle the two decks. Play recommences with the same rules as before, moving the temperature cursor. This time, the students should pay particular attention to what happens – in terms of carbon moves – when the "human activities" cards are drawn.

8. Once the stack of cards is empty, ask them about the carbon content in each reservoir and about the temperature change: *How can you explain these results? Why is the temperature higher this time? How could you limit this increase?* Human activities have increased the amount of carbon dioxide in the atmosphere, by adding the carbon which was previously stored in fossil resources: **this has led to the temperature rise.**



Screenshot of the multimedia animation "Carbon cycle"

WRAP-UP 10 MIN

Hold a classroom discussion to review the previous activity using the **WORKSHEET A4.2** (small version) as a template. Work with your students to draw arrows demonstrating all of the carbon flows they discovered. They can mark the impact of human activities with a different colour. In this way explain that humans have not created more carbon on Earth, but that we move carbon from one place to another more quickly than would naturally happen, and that this has consequences for the climate of the planet.

Encourage students to provide explanations for the processes underlying each of the arrows, focusing on the content appropriate for your grade level. Emphasise the fact that many human activities impact the cycle by reinforcing carbon movement towards the atmosphere. However, we can also act to capture this atmospheric carbon: for example, this is what happens in the case of reforestation.

TEACHER TIP

You may notice a slight difference between the carbon cycle in the gameboard and the one in the multimedia animation programme. We have chosen not to represent the flow between the biosphere and fossil resources ("fossil resource production") in our boardgame because of the huge timescale of this phenomenon, which occurs over several million years. It would not be accurate to represent this flow in the game.

BACKGROUND FOR TEACHERS [1]

Carbon is found in both living and non-living parts of the planet, as a component in organisms, atmospheric gases, water and rocks. It is usually bound to other elements in compounds, such as carbon dioxide, sugars and methane.
Carbon moves from one sphere to another in an ongoing process known as the **carbon cycle,** which is influenced by crucial life processes such as photosynthesis and respiration, contributes to fossil fuel formation, and **impacts the Earth's climate.** For further details on the carbon cycle, see page 10 of the Scientific Overview.

THE CARBON CYCLE IS BOTH FAST AND SLOW

In general, the **short-term carbon cycle** encompasses photosynthesis, respiration and predator–prey transfer of carbon. The **long-term carbon cycle** involves more lithospheric (=rocks) processes. This includes the weathering and erosion of carbon-containing rocks, the accumulation of carbon-rich plant and animal material in sediments, and the slow movement of those sediments through the rock cycle. Despite the diversity of the processes involved, **the natural carbon cycle is balanced.**

HUMANS AFFECT THE CARBON CYCLE

There are natural fluctuations in the carbon cycle, but humans are now changing the carbon flows on earth at an unnatural rate. The major human-induced changes have resulted in an **increase of carbon dioxide in the atmosphere and in an imbalance of the carbon cycle.**
The largest source of this is **burning fossil fuels** but other actions, such as **deforestation and cement manufacturing,** have also contributed to this change in the carbon cycle. Understanding the carbon cycle is especially important at this time in human history because of the dramatic changes we are making to the cycle.

1 This background is inspired by the "Carbon Cycle Roleplay" of the Calacademy. https://www.calacademy.org/educators/lesson-plans/carbon-cycle-role-play

WORKSHEET A4.1

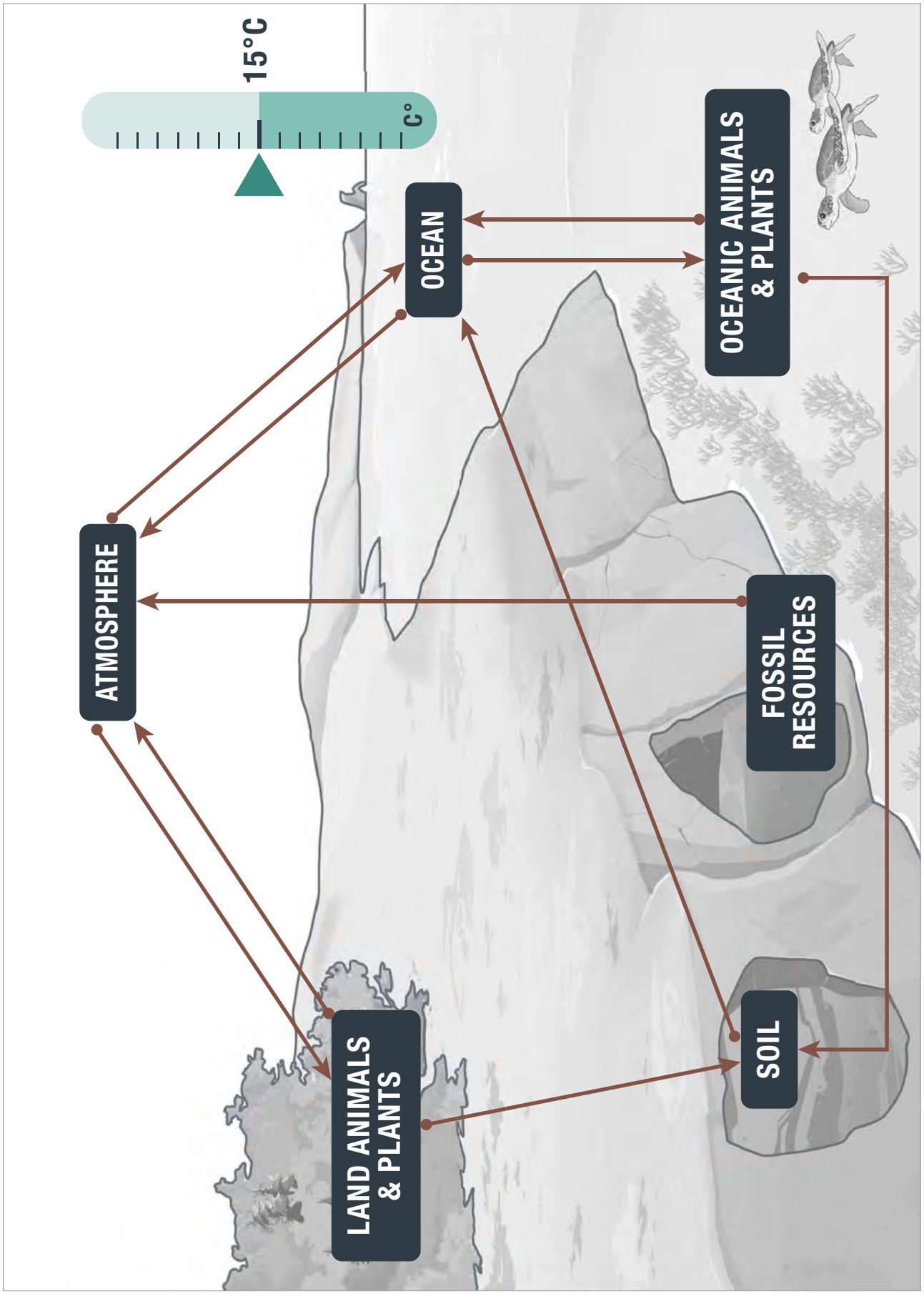
DIVISION OF THE CARBON TOKENS BETWEEN EACH RESERVOIR ACCORDING TO THEIR STOCK

RESERVOIR	STOCKS (GIGATONNES OF CARBON)	NUMBER OF TOKENS TO PUT ON THE GAMEBOARD
Ocean	38,700	25
Atmosphere	829	7
Biosphere: Oceanic animals and plants	about 400	6
Biosphere: Land animals and plants	about 200	6
Soil, rocks and sediments	3750	15
Fossil fuels	1000 - 2000	10

The number of tokens is given as approximate, but it cannot exactly represent the stocks as the ocean stock is ten times higher than the one for soil, for example.

The estimations of the different stocks are taken from the IPCC reports.

WORKSHEET A4.2



LAND PHOTOSYNTHESIS

In sunlight, through photosynthesis, plants produce their organic matter and grow by absorbing carbon dioxide from the atmosphere and taking in water using their roots.

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NATURAL CYCLE

CONTINENTAL SEDIMENTATION

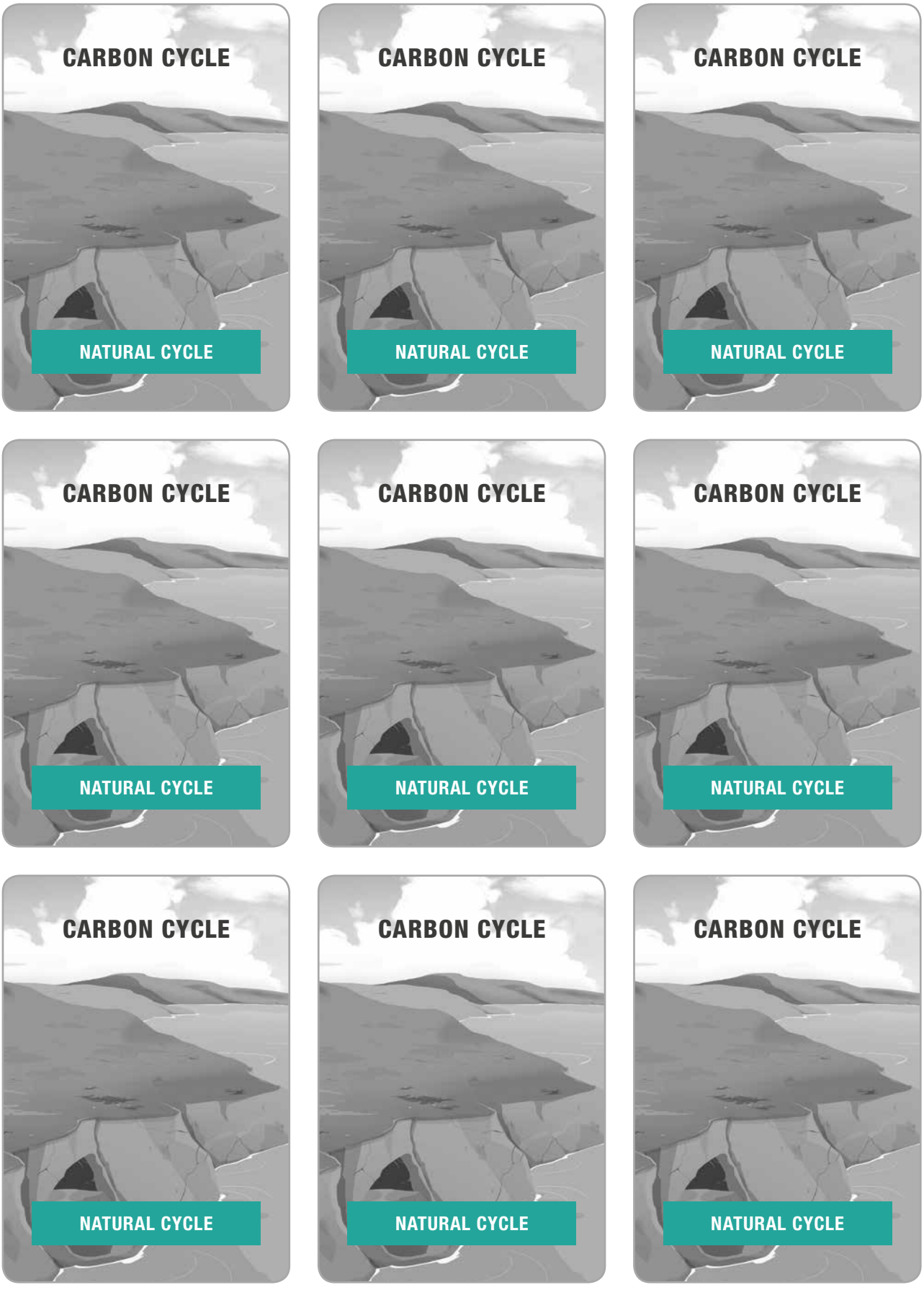
Continental sedimentation is the accumulation of mineral, plant or animal deposits in the soil, on land. Their carbon content is then stored in the soil.

NATURAL CYCLE

OCEANIC SEDIMENTATION

Oceanic sedimentation is the accumulation of mineral, plant or animal deposits in the soil, at the bottom of the ocean. Their carbon content is then stored in the soil.

NATURAL CYCLE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EROSION

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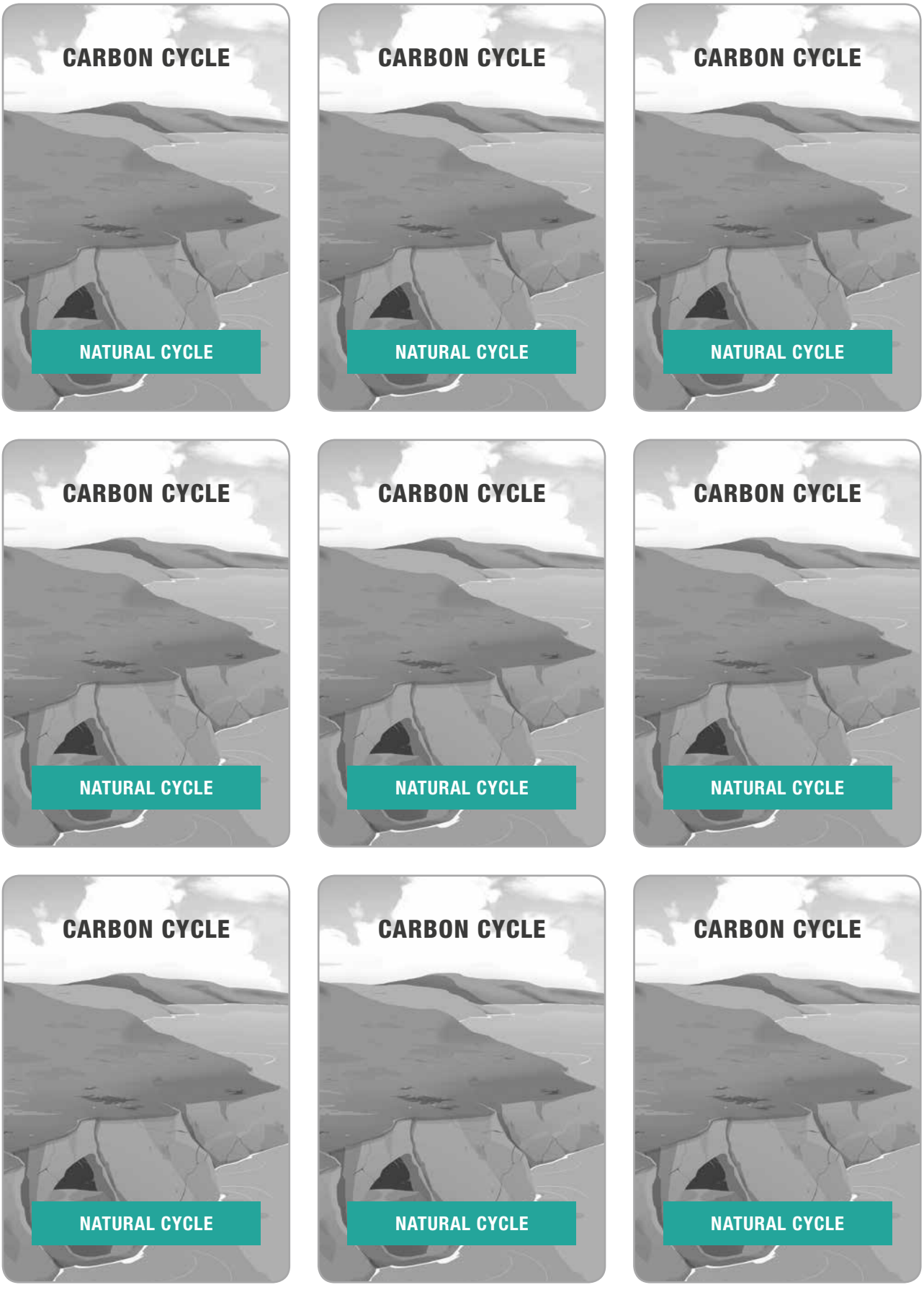
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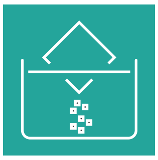
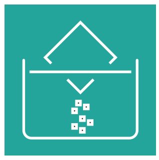


DISSOLUTION

Carbon dioxide from the atmosphere dissolves in water, more easily in cold areas of the ocean.

NATURAL CYCLE



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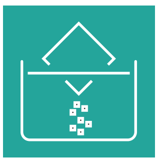

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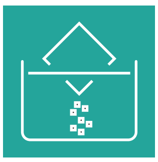

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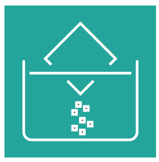

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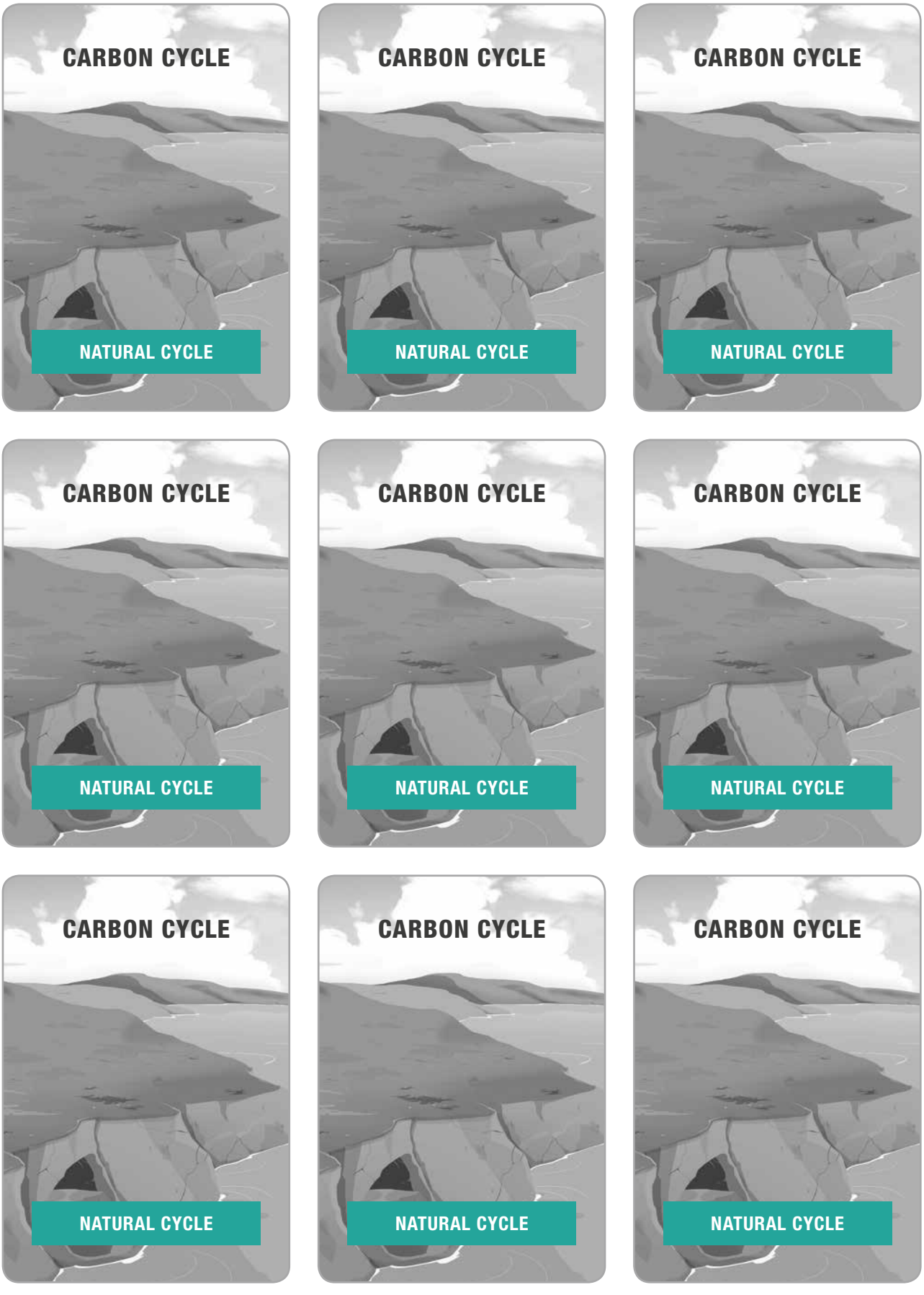
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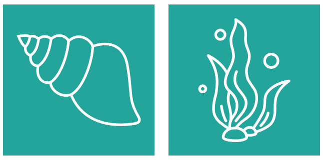
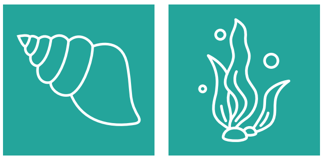


CALCIFICATION & OCEANIC PHOTOSYNTHESIS

Some organisms form shells using carbon dioxide in the water. This carbon dioxide is also consumed by aquatic species who perform photosynthesis in presence of light.

NATURAL CYCLE



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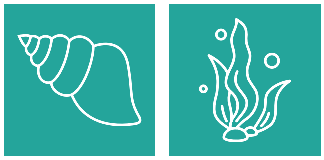

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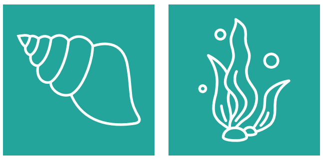

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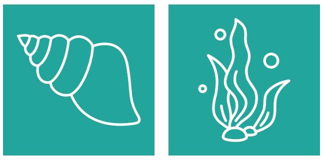

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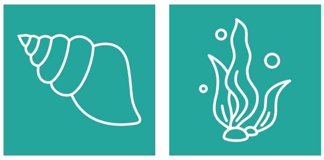

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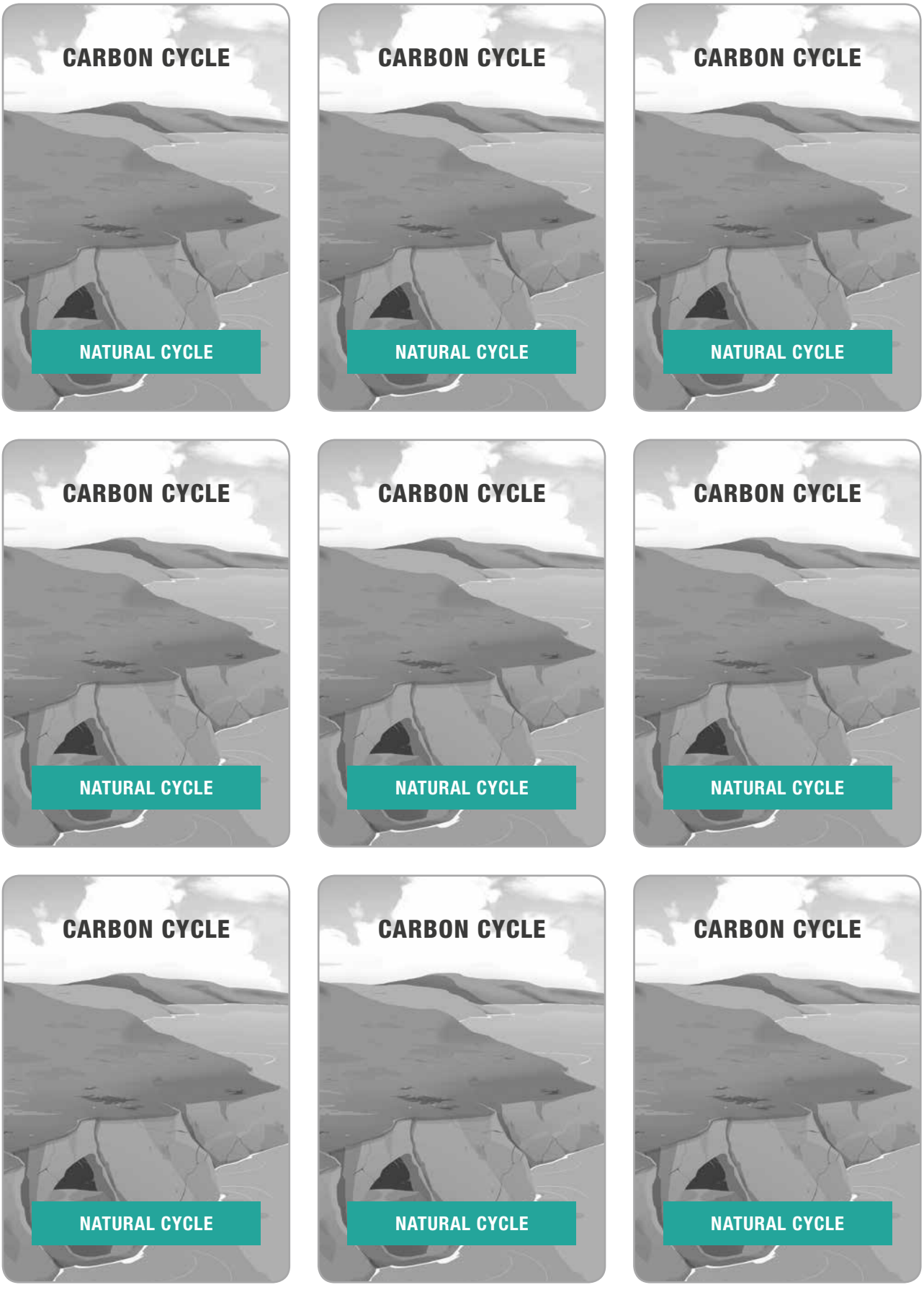
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DEFORESTATION

Deforestation occurs when humans cut down trees to use wood, or burn them to plant crops. Burning causes the release of carbon dioxide into the atmosphere.

HUMAN ACTIVITIES

REFORESTATION

Reforestation is the planting of new trees in areas where they have been removed. The new trees then capture carbon dioxide from the atmosphere through photosynthesis.

HUMAN ACTIVITIES

INDUSTRIES

The industries that manufacture our everyday objects release large quantities of greenhouse gases into the atmosphere, such as carbon dioxide, because they burn fossil resources (coal, oil).

HUMAN ACTIVITIES

TRANSPORTATION

The transportation sector (trucks, cars, boats, airplanes) consumes fossil resources (oil) through combustion. The carbon dioxide produced is then released into the atmosphere.

HUMAN ACTIVITIES

AGRICULTURE

Agriculture requires fossil resources (coal, oil, gas) to produce our food. Livestock, especially cattle, also produce large quantities of methane. This adds carbon to the atmosphere.

HUMAN ACTIVITIES

ENERGY

To produce energy, many power plants on Earth use fossil resources. When they are burned, the carbon dioxide that is produced is released into the atmosphere.

HUMAN ACTIVITIES

WORKSHEET A4.4 PAGE 2/2