Name: _____ Date: _____ Period: _____

Carbon Cycle and Climate Change

MATERIALS

Chemical cards, Sorting It Out page

DIRECTIONS

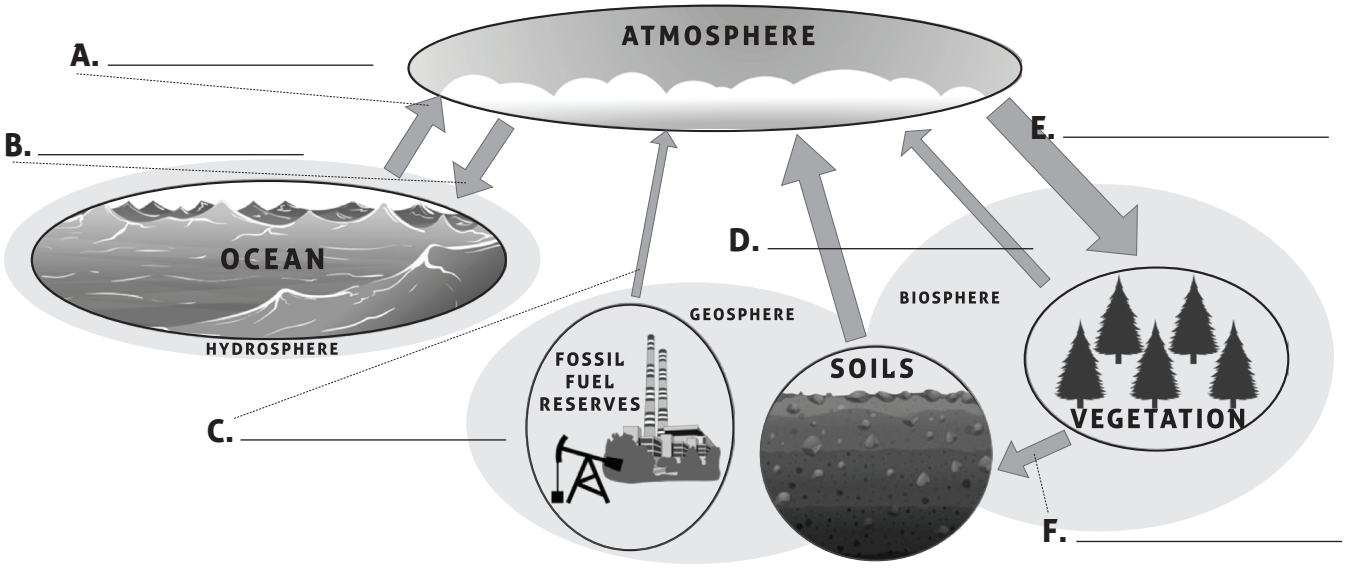
FOR EACH REACTION:

1. Look through the chemical cards and choose the chemicals you think are used as reactants and products. Place the cards in the correct boxes on the Sorting It Out page.
2. Write the chemical formulas for the reactants and products in Table 1 below.
3. Circle the reactant and product that contain carbon.
4. Put the chemical cards back into the stack.

Table 1. Reactants and Products

PHOTOSYNTHESIS		***RESPIRATION***		***COMBUSTION***	
Process used by plants to transform light energy into chemical energy		Process by which organisms use food molecules to produce energy (adenosine triphosphate, ATP) for their cells		Reaction that results in heat and light; in this case, the burning of coal, which is largely composed of carbon	
2 Reactants	***2 Products***	***2 Reactants***	***2 Products***	***2 Reactants***	***1 Product***

5. Label the blanks on the diagram below with the name of the process that moves carbon between the reservoirs by the arrows. Blank D is labeling two arrows pointing toward the Atmosphere, one from Soils and the other from Vegetation.



UP IN THE AIR MODEL

I. *Label and Place the Cups*

Materials: Five small cups, one set of cup labels, tape, scissors, and fluxing carbon pieces

In pencil, write the name of each the reservoirs in the box to the right onto one of each of the cup labels, based on the amount of carbon in the reservoir. Use what you know about how much carbon each of the reservoirs contains to determine which reservoir name to write on each cup label.

Cut out the cup labels and tape each of them to a cup. Place the correctly labeled cups onto the corresponding reservoirs on the model board.

RESERVOIR CHOICES:

Ocean
Soils
Fossil Fuel Reserves
Atmosphere
Vegetation

II. *Place Fluxing Carbon Game Pieces*

Use the table below to place the correct number of fluxing carbon pieces in each of the reservoir cups on the model board. Pieces represent fluxing carbon during the 1-year period of the game.

Important: each reservoir must contain at least ten 1 PgC pieces, except the fossil fuel reservoir.

Table 2. Amount of fluxing carbon in each reservoir during the 1-year period of the game

Reservoir	*Approx. Fluxing Carbon (Pg)*
Vegetation	44
Fossil fuel reserves	8
Ocean	80
Soils	75
Atmosphere	201

Data Sources: Ciais et al. (2013), IPCC and Ch. 6 Schlesinger and Andrews (2000)

III. *Play the Game*

Materials: One set of game cards

Follow the instructions below to play the game, and then answer the game questions.

A. Shuffle the game cards and place them face down.

B. The youngest player will go first.

C. Player 1 draws the first card and moves fluxing carbon pieces from one reservoir to another based on the process listed on the card.

   a. Determine which reservoirs to transfer carbon between based on the process listed on the card.

D. Each player will **keep the game cards that they draw in a stack next to themselves**.

E. Take turns drawing cards and moving fluxing carbon pieces until all cards have been used.

F. Once you finish with the game cards, the game is over. **Keep each player's game cards next to them, and leave all of the fluxing carbon pieces in place on the game board**.

Game Questions

6. Look at the game cards that you drew during the game, and **find the ones with the "A" in the top right corner**. These cards indicate carbon that you moved to the atmosphere.

   Determine the amount of fluxing carbon that you **moved to the atmosphere** by adding up the amount of carbon on each of your game cards labeled "A."

   Your fluxing atmospheric carbon: _____ Pg

7. Check with your partner(s). How much fluxing carbon **did your partner move to the atmosphere**?

   Your partner's fluxing atmospheric carbon: _____ Pg

8. Who won? _____
   Name of player who moved the **least** fluxing C to atmosphere

9. Find the total fluxing atmospheric carbon at the end of the game.

   _____ Pg + _____ Pg = _____ Pg
   Your fluxing atmospheric C | Partner's fluxing atmospheric C | Total fluxing atmospheric C

10. How much fluxing carbon was added to the atmosphere during the 1-year period of the game?

    _____ Pg – _____ Pg = _____ Pg
    Total fluxing atmospheric C at end of game (question 9) | Total fluxing atmospheric C at start of game (p. 2, sec. II) | Fluxing atmospheric C added during 1-year period of game

    How many blue whales could you use to represent the amount of carbon that is being added to the atmosphere every year? (1 PgC = approximately 6 million blue whales)

11. From which reservoirs is carbon fluxing **to** the atmosphere, but carbon is not fluxing **from** the atmosphere? In other words, on the game board, which reservoirs have an arrow pointing to the atmosphere but none pointing from the atmosphere back to the reservoir?

    Of these reservoirs, which is a more recent source of carbon to the atmosphere?

12. Do you think the flux of carbon into the atmosphere from fossil fuels accounts for the increase in greenhouse gases, such as carbon dioxide, that are affecting Earth's climate? Why or why not?

13. Was carbon ever removed from or added to Earth during the game?

Can carbon be created or destroyed?

Conclusion

14. How are humans impacting the cycling of carbon on Earth?

What effects are these changes to the carbon cycle having on Earth's systems?

Extension: Critiquing the Model

15. Which parts of the game were effective at modeling the reservoirs and fluxing of carbon? Why?

16. Which parts of the game were not effective at modeling the reservoirs and fluxing of carbon? Why?

ANSWER KEY

Carbon Cycle and UP IN THE AIR Climate Change

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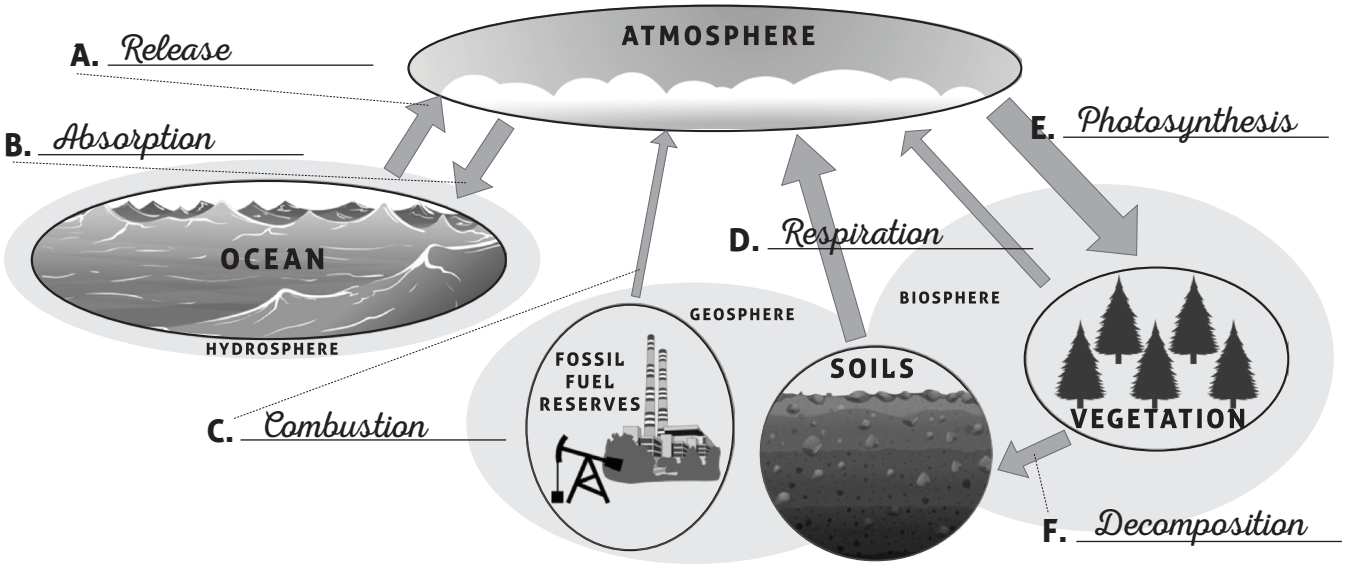
2 Reactants	*2 Products*	*2 Reactants*	*2 Products*	*2 Reactants*	*1 Product*
CO_2 H_2O	$C_6H_{12}O_6$ O_2	$C_6H_{12}O_6$ O_2	CO_2 H_2O	C O_2	CO_2

5. Label the blanks on the diagram below with the name of the process that moves carbon between the reservoirs by the arrows. Blank D is labeling two arrows pointing toward the Atmosphere, one from Soils and the other from Vegetation.



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Cut out the cup labels and tape each of them to a cup. Place the correctly labeled cups onto the corresponding reservoirs on the model board.

RESERVOIR CHOICES:

Ocean
Soils
Fossil Fuel Reserves
Atmosphere
Vegetation

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   a. Determine which reservoirs to transfer carbon between based on the process listed on the card.

D. Each player will **keep the game cards that they draw in a stack next to themselves**.

E. Take turns drawing cards and moving fluxing carbon pieces until all cards have been used.

F. Once you finish with the game cards, the game is over. **Keep each player's game cards next to them, and leave all of the fluxing carbon pieces in place on the game board**.

Game Questions

6. Look at the game cards that you drew during the game, and **find the ones with the "A" in the top right corner**. These cards indicate carbon that you moved to the atmosphere.

   Determine the amount of fluxing carbon that you **moved to the atmosphere** by adding up the amount of carbon on each of your game cards labeled "A."

   Your fluxing atmospheric carbon: *Student answers will vary* Pg

7. Check with your partner(s). How much fluxing carbon **did your partner move to the atmosphere**?

   Your partner's fluxing atmospheric carbon: *Student answers will vary* Pg

8. Who won? *Student answers will vary*
   Name of player who moved the **least** fluxing C to atmosphere

9. Find the total fluxing atmospheric carbon at the end of the game.

   Student answers will vary Pg (Your fluxing atmospheric C) + *Student answers will vary* Pg (Partner's fluxing atmospheric C) = *207* Pg (Total fluxing atmospheric C)

10. How much fluxing carbon was added to the atmosphere during the 1-year period of the game?

    207 Pg (Total fluxing atmospheric C at end of game (question 9)) – *201* Pg (Total fluxing atmospheric C at start of game (p. 2, sec. II)) = *6* Pg (Fluxing atmospheric C added during 1-year period of game)

    How many blue whales could you use to represent the amount of carbon that is being added to the atmosphere every year? (1 PgC = approximately 6 million blue whales)

    6 PgC (6 million blue whales/PgC) = 36 million blue whales

11. From which reservoirs is carbon fluxing **to** the atmosphere, but carbon is not fluxing **from** the atmosphere? In other words, on the game board, which reservoirs have an arrow pointing to the atmosphere but none pointing from the atmosphere back to the reservoir?

    Soils and Fossil Fuel Reserves

    Of these reservoirs, which is a more recent source of carbon to the atmosphere?

    Fossil Fuel Reserves

12. Do you think the flux of carbon into the atmosphere from fossil fuels accounts for the increase in greenhouse gases, such as carbon dioxide, that are affecting Earth's climate? Why or why not?

    Answers may vary but should include something related to how the flux from fossil fuels (8 PgC) each year drastically increases the amount of greenhouse gases in the atmosphere, resulting in warming.

13. Was carbon ever removed from or added to Earth during the game?

    No

Can carbon be created or destroyed?

No

Conclusion

14. How are humans impacting the cycling of carbon on Earth?

Humans are increasing the amount of carbon dioxide in the atmosphere. Answers could also include deforestation, degradation of soils, ocean acidification, and others.

What effects are these changes to the carbon cycle having on Earth's systems?

Possible answers include: the increase in atmospheric carbon dioxide will result in increasing temperatures and other impacts to Earth's systems such as extreme weather events driven by rising sea temperatures, increased frequency of wildfires, and increased sea levels; deforestation reduces the amount of carbon being removed from the atmosphere through photosynthesis; as the ocean absorbs carbon, it becomes more acidified making it less efficient at absorbing additional carbon dioxide.

Extension: Critiquing the Model

15. Which parts of the game were effective at modeling the reservoirs and fluxing of carbon? Why?

Possible answers include: placing the cup labels (the non-fluxing carbon) on the reservoir cups to represent the carbon that did not move during the game, moving the fluxing carbon pieces from reservoir to reservoir and having those game pieces represent different amounts of carbon, the values of carbon in each reservoir and flux were based on actual data.

16. Which parts of the game were not effective at modeling the reservoirs and fluxing of carbon? Why?

Possible answers include: the reservoirs on the board were not scaled to represent either their relative physical sizes or amount of carbon, it was conducted over too short of a timeframe (only one year), there is no key on the game board, the cup labels/non-fluxing carbon and fluxing carbon pieces were not scaled accurately to represent relative amounts of carbon, there are reservoirs missing (animals, rocks, minerals, etc.).