Name ______________________________ Teacher ________________ Date __________

4.3: Tiny World Modeling Worksheet

The annual cycle. There's a striking pattern in the data on CO_2 concentrations in Hawaii (the Keeling Curve). Every fall and winter the concentration of CO_2 in the air around Hawaii goes up, reaching a peak in May, then every spring and summer the concentration goes back down, reaching a minimum in October. How can we explain this pattern?

The long-term trend. And there's another pattern, too. Every year there's a little more CO_2 in the atmosphere than there was the year before. How can we explain this pattern?

Earth systems include carbon **pools**—different forms of organic carbon and CO_2—and carbon **fluxes**—processes that move carbon atoms from one pool to another. Carbon fluxes cause pools to get bigger or smaller. A good explanation uses pools and fluxes to answer the Large Scale Four Questions:

1. The Carbon Pools Question: Where are the carbon pools in our environment?
2. The Carbon Cycling Question: How are carbon atoms cycling among pools?
3. The Energy Flow Question: How does energy flow through environmental systems?
4. The Stability and Change Question: How do carbon fluxes change the size of carbon pools?

When you explain the annual cycle in CO_2 concentrations in Hawaii, it is especially important to answer the Stability and Change Question. You can see how this works by playing the Tiny World Pool and Flux Game. This game has a tiny world that has three carbon pools (Atmospheric CO_2; Organic Matter in Plants, Animals, and Soil; and Fossil Fuels) and three carbon fluxes (Photosynthesis, Cellular Respiration, and Combustion).

You can use this game to figure out how pools and fluxes explain the annual cycle and the long-term trend.

A. Playing the Game

Here's what you will need besides this worksheet:

1. The Tiny Pool and Flux Placemat
2. 30 carbon atoms (from your molecule kits, or other counters such as pennies)

Each scenario in the tables below is a different game. Here's how to play:

1. Start each game with 20 atoms in the Fossil Fuel pool on the placemat.
2. Look at the numbers for Year 0 in the table to see how many atoms go the Organic and Atmospheric Pools. (The Tiny World is like the Earth today in that the Organic Carbon Pool is much larger than the Atmospheric Carbon Pool Put two different-colored dots on the graph showing how many atoms are in each pool.
3. Each game has ten turns of one half year each. For each turn you:
    - Move the numbers of atoms showing in the three fluxes.
    - Record the new numbers of atoms in each pool
    - Put new dots on the graph for each pool and connect the dots with lines.

What is happening in this world to the amount of organic carbon?

Try these different scenarios.

Scenario 1: A world with no seasons and balanced fluxes. In this scenario, there is an overall balance in the ecosystems of the Tiny World, with photosynthesis by producers balanced by the cellular respiration of producers, consumers and decomposers. Try playing the game with the starting points below, record your results, and write down a different set of starting numbers that would produce the same results.

Scenario #1: No seasons and balanced fluxes

Photosynthesis:	**2** carbon atoms/.0 yr and .5 y.
Cellular Respiration:	**2** carbon atoms/.0 yr and .5 yr
Combustion:	**0** carbon atoms/.0 yr and .5 yr

Year	**Organic Pool (# carbon atoms)**	**Atmospheric Pool (# carbon atoms)**
0	**15**	**5**
.5		
1		
1.5		
2		
2.5		
3		
3.5		
4		
4.5		
5		

What is happening in this world to the amount of atmospheric carbon? ____________________

____

Find some different fluxes that will produce the same graph:

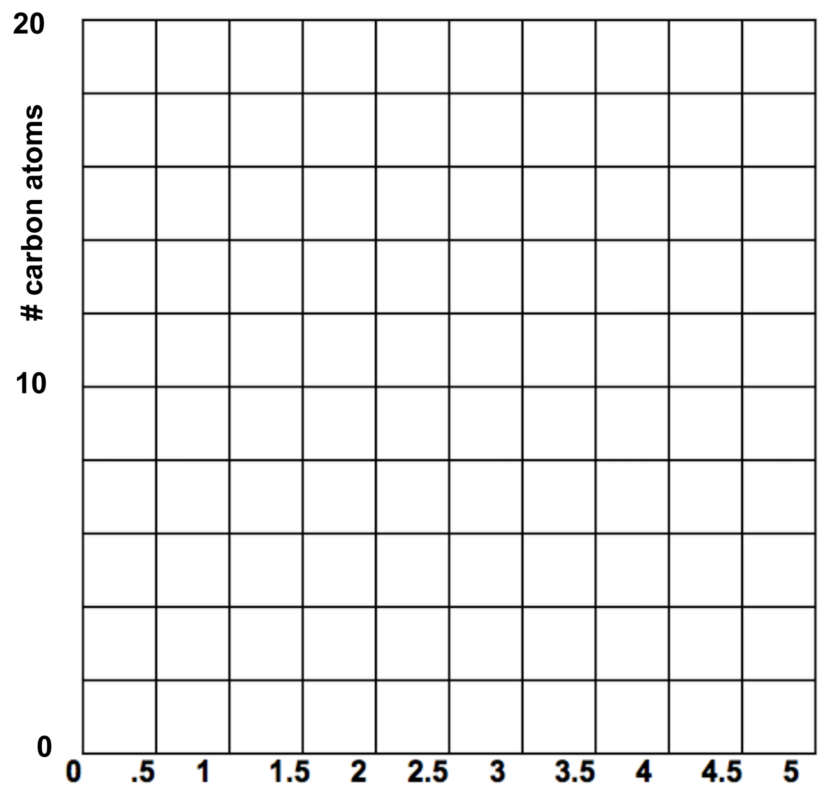
Photosynthesis: _____

Cellular respiration: _____

Combustion: _____

Graph Key

Organic pool color:__________	**Atmospheric pool color:**__________



Scenario 2: A world with seasons and balanced fluxes. Now let's try adding seasons to the Tiny World. This world can have just two seasons: summer and winter. In this scenario all the photosynthesis takes place in the summer. Cellular respiration continues both summer & winter, since plants, animals, and decomposers stay alive through the winter. In this scenario the whole years (0, 1, 2, etc.) are the end of winter, while the half years (0.5, 1.5, 2.5, etc.) are the end of summer. Try playing the game with the starting points below, record your results, and write down a different set of starting numbers that produce the same results.

Scenario #2: Seasons and balanced fluxes

Photosynthesis:	**4** carbon atoms/.5 yr. **0** carbon atoms/.0 yr
Cellular Respiration:	**2** carbon atom/.0 yr and .5 yr
Combustion:	**0** carbon atom/.0 yr and .5 yr

Year	Organic Pool (# carbon atoms)	Atmospheric Pool (# carbon atoms)
0	15	5
.5		
1		
1.5		
2		
2.5		
3		
3.5		
4		
4.5		
5		

What is happening in this world to the amount of atmospheric carbon? ____________________

____

Find some different fluxes that will produce the same graph:

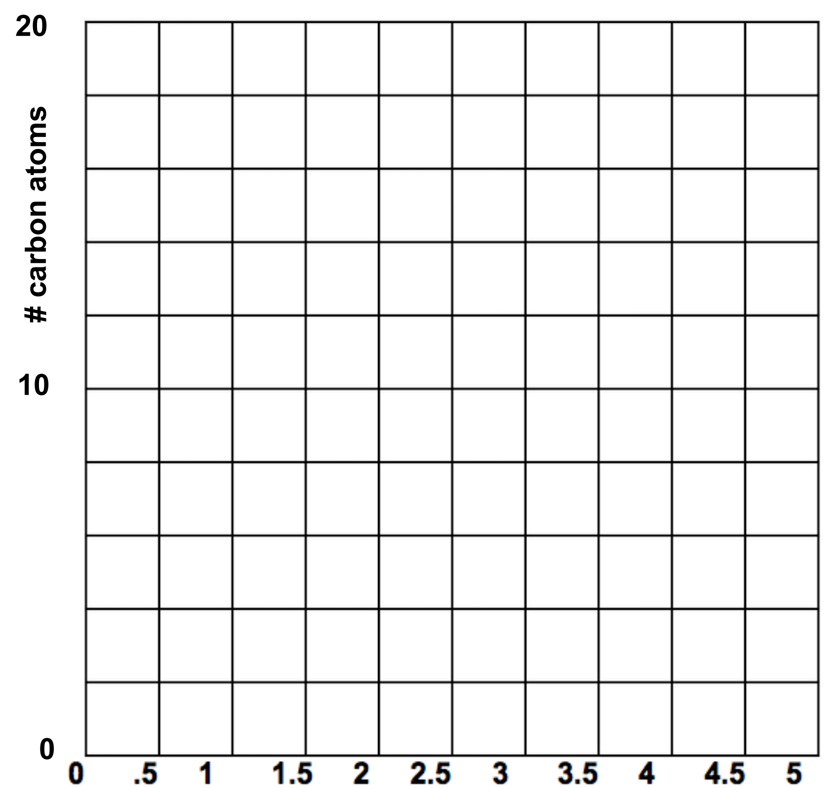
Photosynthesis: _____

Cellular respiration: _____

Combustion: _____

Graph Key

Organic pool color:__________	Atmospheric pool color:__________



Scenario 3: A world with no seasons and fossil fuel combustion. Now suppose that the Tiny World has people who are burning some fossil fuels every year. Try playing the game with these numbers and see what happens!

Scenario #3: No seasons and fossil fuel combustion			
Photosynthesis:	**2** carbon atom/.0 yr and .5 y	**Graph Key**	
Cellular Respiration:	**2** carbon atom/.0 yr and .5 yr	**Organic pool color:__________**	**Atmospheric pool color:__________**
Combustion:	**1** carbon atom/.0 yr and .5 yr		

Year	**Organic Pool (# carbon atoms)**	**Atmospheric Pool (# carbon atoms)**
0	**15**	**5**
.5		
1		
1.5		
2		
2.5		
3		
3.5		
4		
4.5		
5		

What is happening in this world to the amount of atmospheric carbon? ____________________

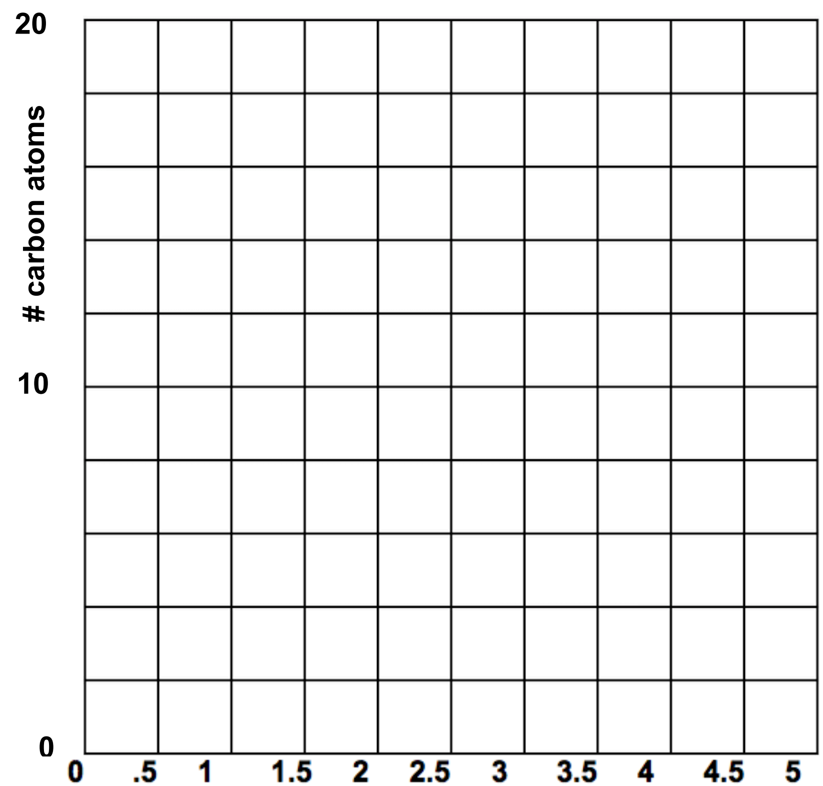
____

Find some different fluxes that will produce the same graph:

Photosynthesis: _____

Cellular respiration: _____

Combustion: _____



Scenario 4: A world with seasons and fossil fuel combustion. Now suppose that the Tiny World has both seasons and people who are burning some fossil fuels every year. Try playing the game with these numbers and see what happens!

Scenario #4: Seasons and fossil fuel combustion		
Photosynthesis:	**4** carbon atoms/.5 yr. **0** carbon atoms/.0 y	**Graph Key**
Cellular Respiration:	**2** carbon atoms/.0 yr and .5 yr	**Organic pool color:**__________ **Atmospheric pool color:**__________
Combustion:	**1** carbon atom/.0 yr and .5 yr	

Year	**Organic Pool (# carbon atoms)**	**Atmospheric Pool (# carbon atoms)**
0	**15**	**5**
.5		
1		
1.5		
2		
2.5		
3		
3.5		
4		
4.5		
5		

What is happening in this world to the amount of atmospheric carbon? ____________________

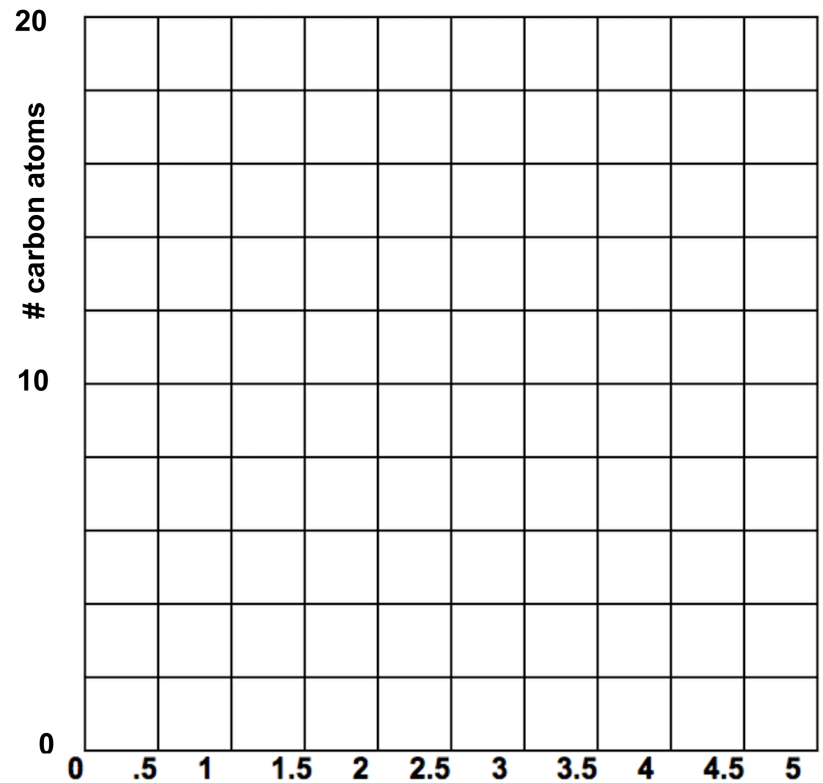
____

Find some different fluxes that will produce the same graph:

Photosynthesis: _____

Cellular respiration: _____

Combustion: _____



B. Explaining the annual cycle for CO_2 concentrations in Hawaii

Now try writing an explanation that answers the Four Questions: *Why do CO_2 concentrations in Hawaii go down every summer and up every winter?* Start by making notes about each question, then try combining those notes into a complete explanation.

Question	***Your Notes***
The Carbon Pools Question: What are the carbon pools that are involved in the annual cycle?	
The Carbon Cycling Question: How are carbon atoms cycling between those pools?	
The Energy Flow Question: How does energy flow through those carbon pools?	
The Stability and Change Question: How do carbon fluxes change the size of carbon pools?	

Now try combining your notes into a paragraph that has a complete explanation.

C. Explaining the long-term trend for CO_2 concentrations in Hawaii

Now try writing an explanation for the long-term trend that answers the Four Questions: *Why is there a little more CO2 in the atmosphere each year?* Start by making notes about each question, then try combining those notes into a complete explanation.

Question	***Your Notes***
The Carbon Pools Question: What are the carbon pools that are involved in the long-term trend?	
The Carbon Cycling Question: How are carbon atoms cycling between those pools?	
The Energy Flow Question: How does energy flow through those carbon pools?	
The Stability and Change Question: How do carbon fluxes change the size of carbon pools?	

Now try combining your notes into a paragraph that has a complete explanation.