

4.3: Grading Tiny World Modeling Worksheet

*This tool has “grading” in the title because at this point, students can be held accountable for correct answers. Level 4 (correct) responses to the questions are in **blue bold italics** below. There are also comments about common Level 2 and Level 3 responses to help you with grading and making decisions about what to emphasize in future lessons.*

Red italics suggest ways to grade student responses by giving them points for correct or partially correct answers. There are XX points total on this worksheet.

The annual cycle. There’s a striking pattern in the data on CO₂ concentrations in Hawaii (the Keeling Curve). Every fall and winter the concentration of CO₂ 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 CO₂ 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 CO₂—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 CO₂ 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 CO₂, Biomass, 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. 20 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.

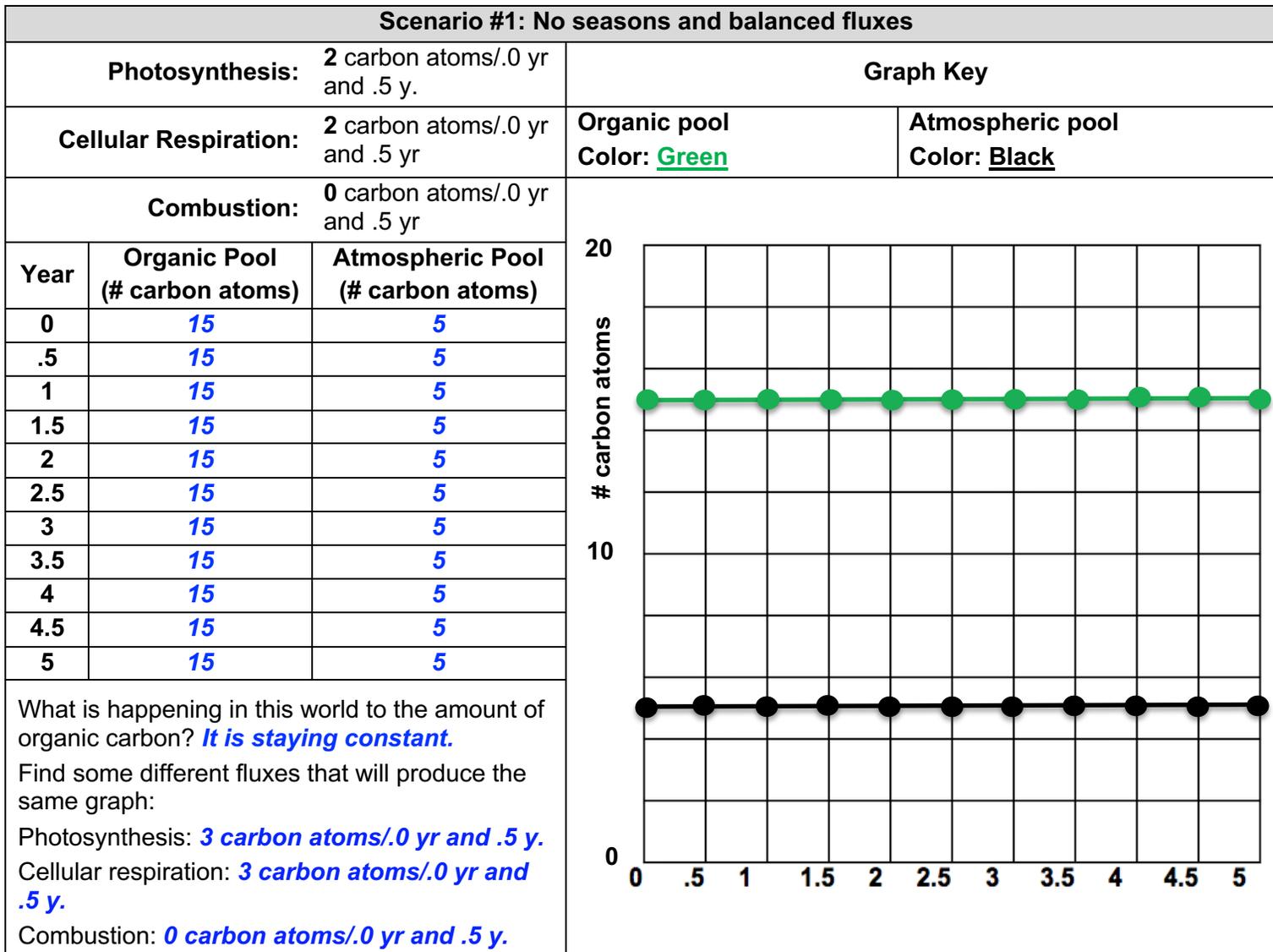
For each scenario:

- *2 points for correct numbers and graph for organic carbon pool*
- *2 points for correct numbers and graph for atmosphere CO₂ pool*

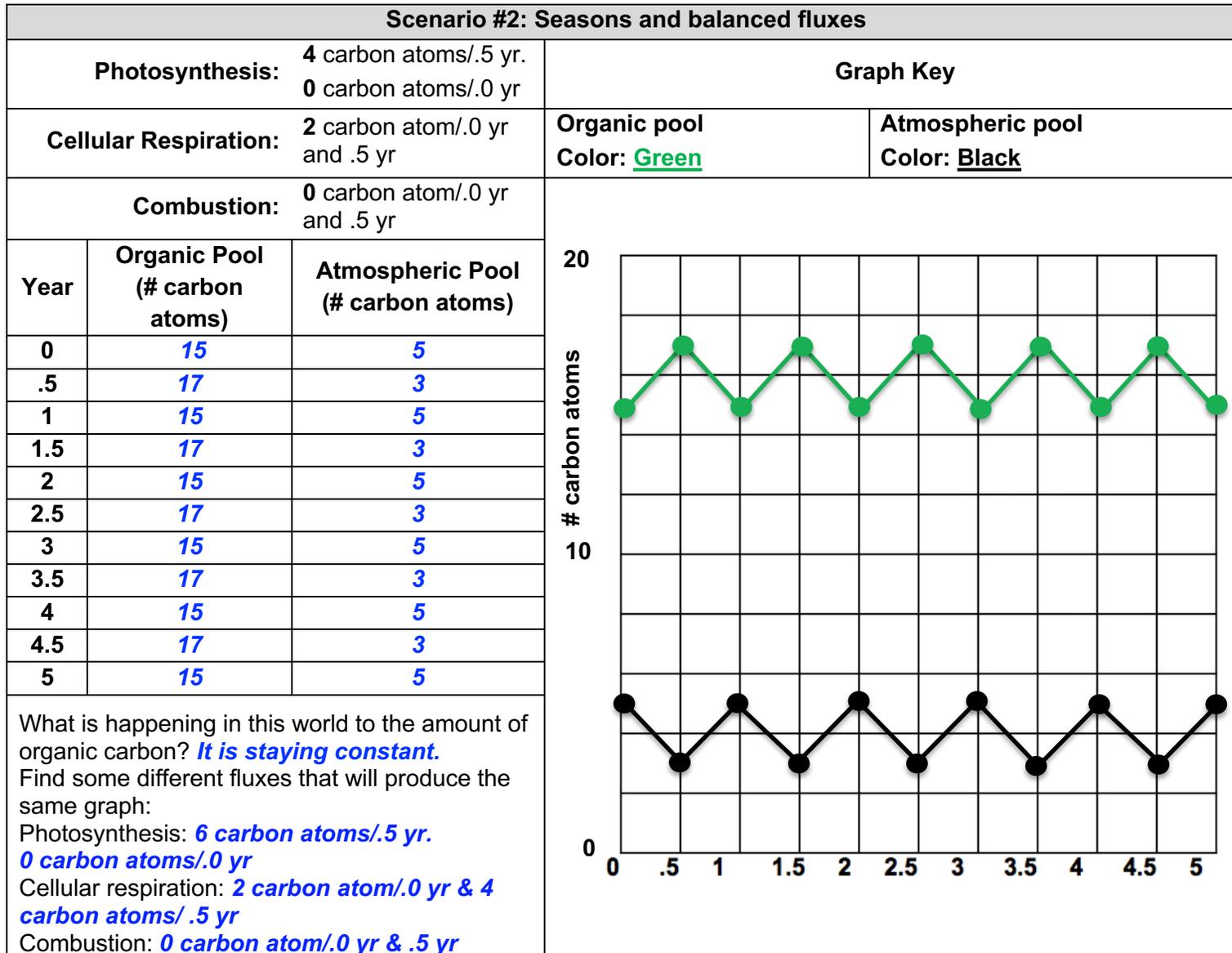
16 points total for 4 scenarios

NOTE: In addition to the correct answers shown on each scenario for other fluxes that would produce the same graphs, there are also other possible combinations of fluxes.

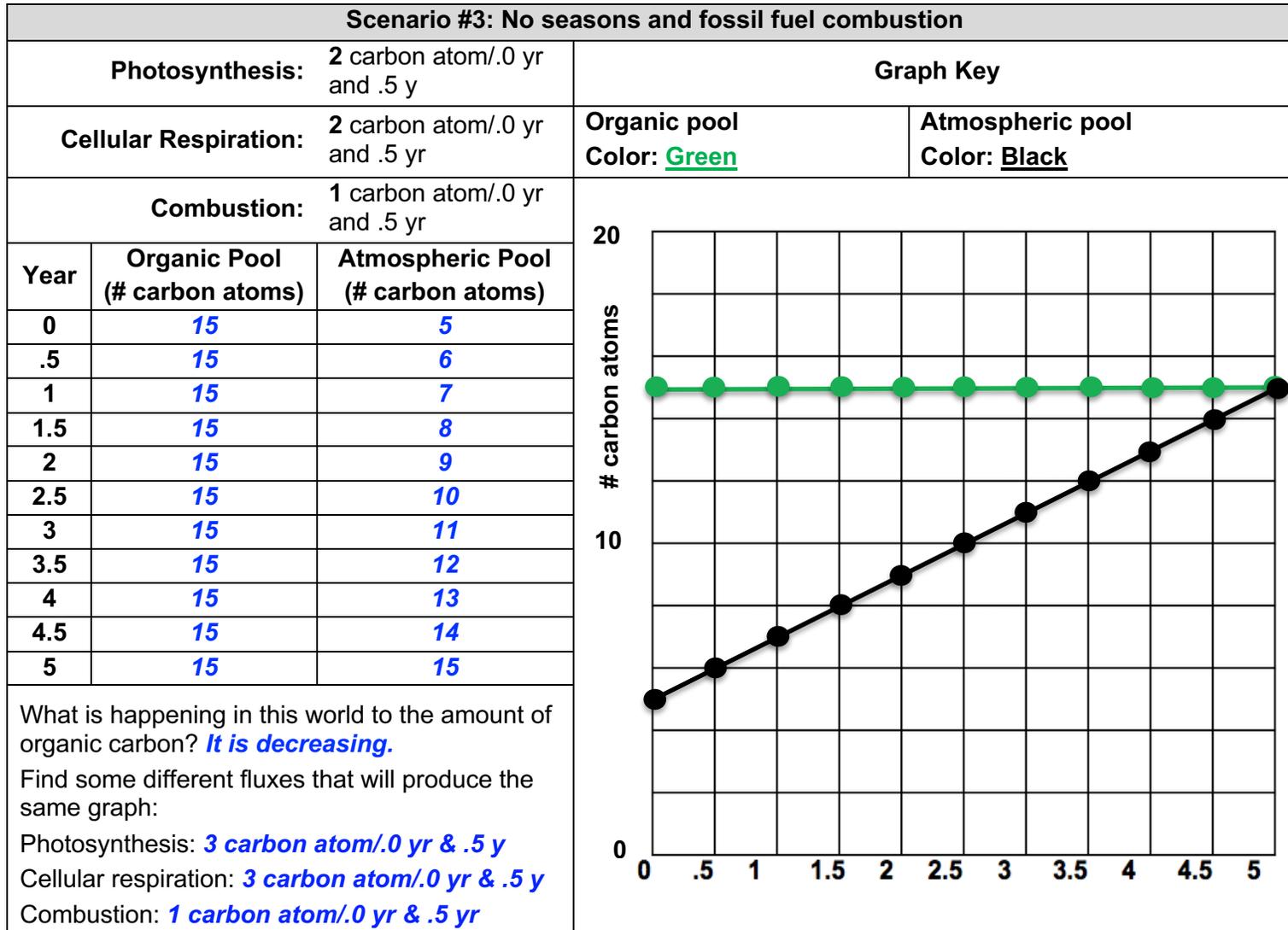
Scenario 1: A world with no seasons and balanced fluxes. In this scenario, there is an overall balance in the ecosystems of the Tiny World, with photosynthesis by producers balanced by the cellular respiration of producers, consumers and decomposers. Try playing the game with the starting points below,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



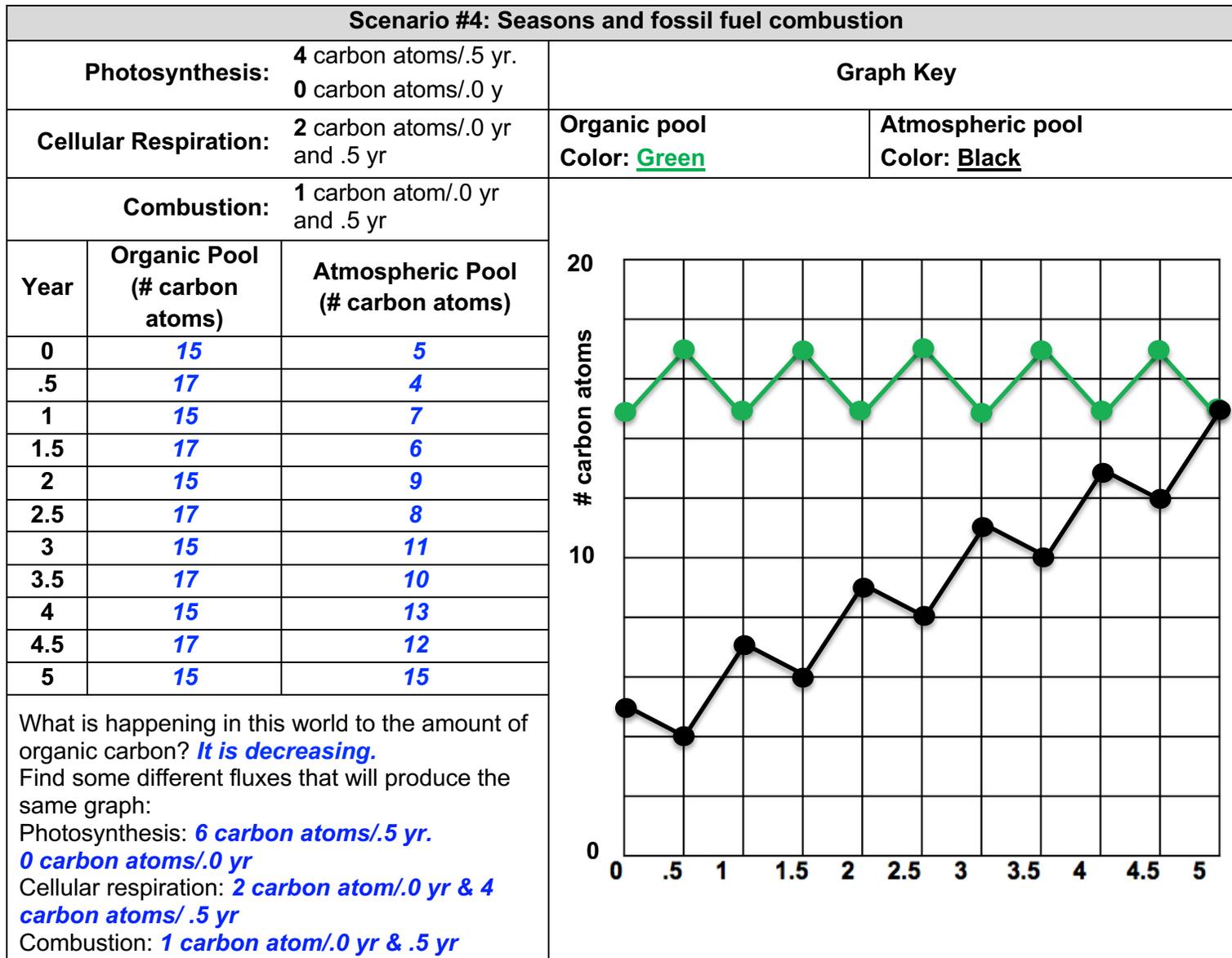
Scenario 2: A world with seasons and balanced fluxes. Now let's try adding seasons to the Tiny World. This world can have just two seasons: summer in winter. In this scenario all the photosynthesis takes place in the summer. Cellular respiration continues both summer & winter, since plants, animals, and decomposers stay alive through the winter. In this scenario the whole years (0, 1, 2, etc.) are the end of summer, while the half years (0.5, 1.5, 2.5, etc.) are the end of winter. 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 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 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!



B. Explaining the annual cycle for CO₂ concentrations in Hawaii

Now try writing an explanation that answers the Four Questions: *Why do CO₂ 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?	Two pools: <ul style="list-style-type: none">• Atmospheric CO₂ pool• Organic carbon in plants, animals, decomposers
The Carbon Cycling Question: How are carbon atoms cycling between those pools?	Two fluxes: <ul style="list-style-type: none">• Photosynthesis: moves carbon from atmosphere to organic carbon, mostly in the summer• Cellular respiration: moves carbon from organic carbon to atmosphere, in summer and winter
The Energy Flow Question: How does energy flow through those carbon pools?	Photosynthesis changes light energy from the sun to chemical energy in organic molecules Cellular respiration changes chemical energy in organic molecules to energy for body functions, motion, and heat.
The Stability and Change Question: How do carbon fluxes change the size of carbon pools?	The atmospheric CO₂ pool gets smaller in the summer, when there is more photosynthesis than cellular respiration. The atmospheric CO₂ pool gets larger in the winter, when there is more cellular respiration than photosynthesis.

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

C. Explaining the long-term trend for CO₂ 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?	<p>Three pools:</p> <ul style="list-style-type: none"> • Atmospheric CO₂ pool • Organic carbon in plants, animals, decomposers • Fossil fuels pool (organic carbon)
The Carbon Cycling Question: How are carbon atoms cycling between those pools?	<p>Three fluxes:</p> <ul style="list-style-type: none"> • Photosynthesis: moves carbon from atmosphere to organic carbon • Cellular respiration: moves carbon from organic carbon to atmosphere • Combustion: moves carbon from fossil fuels to atmosphere
The Energy Flow Question: How does energy flow through those carbon pools?	<p>Photosynthesis changes light energy from the sun to chemical energy in organic molecules</p> <p>Cellular respiration changes chemical energy in organic molecules to energy for body functions, motion, and heat.</p> <p>Combustion changes chemical energy in organic molecules to heat energy that humans use for many purposes.</p>
The Stability and Change Question: How do carbon fluxes change the size of carbon pools?	<p>Over long periods of time, the photosynthesis and cellular respiration fluxes are balanced, so they do not change the atmospheric CO₂ pool.</p> <p>Combustion of fossil fuels is an unbalanced flux, so it increases the atmospheric CO₂ pool.</p>

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