



## HANDS-ON ACTIVITY

## Lungs of the Planet

Why do people call rain forests the lungs of the planet? Usually it is because people think that the rain forests produce most of the oxygen we breathe. But do they? To answer this question, we have to be familiar with two processes that occur within the cells of plants: photosynthesis and cellular respiration. These processes can be described by the following chemical equations:

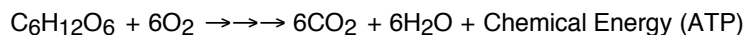
## MATERIALS

- pencil
- ruler

Photosynthesis:



Cellular respiration:



One aspect of photosynthesis that is not reflected in the first equation above is that plants often face a trade-off between gathering carbon dioxide and losing water.

To gather carbon dioxide, they open small pores in the leaf called stomata. When they open these pores, water is usually lost to the environment. The hotter and drier the air is, the faster water is lost. If plants lose too much water, then they may dry out and die.

## ANALYZE

1. Based on the equations above, describe how the processes of photosynthesis and cellular respiration relate to each other.

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2. If a plant is growing by incorporating carbon into its body, is the rate of photosynthesis or the rate of cellular respiration higher? Explain your answer.

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3. Using the photosynthesis equation, predict how the rate of photosynthesis might change with variation in the following parameters (assuming that the plant is not receiving the maximum amount it can use):

- a. The amount of light hitting a leaf

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b. The availability of water

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c. The amount of carbon dioxide in the atmosphere

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d. The air temperature when water is a limiting factor

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4. Based on your answers above, describe how you would expect the *relative* rates of photosynthesis and cellular respiration to vary in rain forests from day to night.

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Steve has collected a lot of data on photosynthetic rates of tropical rain forest plants. Data from one canopy plant and one understory plant are presented in Table 1 below. Each value is the average photosynthetic rate of ten leaves from one individual plant. All measurements were taken during the day. Ten trees were tested in high light (sunny day) and ten were tested in low light (cloudy day) for both the canopy and understory.

5. Complete Data Table 1 by calculating the average rates of photosynthesis.

**Data Table 1. Photosynthesis rates of canopy and understory leaves under high light and low light conditions. Values are average  $\mu\text{MOL CO}_2$  per  $\text{m}^2$  per second for ten leaves from an individual tree.**

INDIVIDUAL	HIGH LIGHT		LOW LIGHT	
	CANOPY	UNDERSTORY	CANOPY	UNDERSTORY
1	10	2.5	1	3
2	12	1.5	0.5	2
3	10	2.5	1	4
4	10.5	2	1.5	2.5
5	12	1.5	1	3
6	10	1.5	1	3
7	11	1	0.5	2
8	9	2.5	1.5	4
9	13	1.5	1	3
10	8	2.5	2	3
<b>Average</b>				

6. In your Evidence notebook, draw a bar graph of the average photosynthetic rates of canopy and understory leaves under high and low light conditions.
7. Are leaves from one area of the rain forest more efficient at photosynthesis under all conditions? Explain.

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Rain forest plants can produce a lot of oxygen during photosynthesis, but they also need to consume oxygen during cellular respiration. So how much oxygen is being produced by rain forests? To address this question, Steve measures the total amount of carbon dioxide that is produced and consumed by the forest. Net ecosystem exchange (NEE) measures the net exchange of carbon dioxide between the ecosystem and the atmosphere.

8. How many molecules of oxygen are produced for every molecule of carbon dioxide that is consumed during photosynthesis?
9. How would you use this relationship to investigate the amount of oxygen being produced if we can only measure changes in the amount of carbon dioxide moving in and out of the plants in the forest?

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Data Table 2 below shows the daily pattern of NEE that Steve has found in the rain forest in Costa Rica. The values provided are the averages for each time period based on measurements over many days. Positive values indicate that, overall, carbon dioxide is being produced and oxygen is being used (that is, cellular respiration is greater than photosynthesis). Negative values mean that, overall, carbon dioxide is being used and oxygen is being produced (that is, photosynthesis is greater than cellular respiration).

**DATA TABLE 2. NET ECOSYSTEM EXCHANGE (NEE) IN A TROPICAL FOREST IN COSTA RICA**

TIME OF DAY	NEE ( $\mu\text{mol CO}_2$ per $\text{m}^2$ per second)
0000	7.0
0200	7.5
0400	5.5
0600	5.0
0800	5.0
1000	-16.0
1200	-16.0
1400	-12.5
1600	-5.0
1800	0.0
2000	5.0
2200	6.5

10. In your Evidence Notebook, draw a line graph of changes in NEE throughout the day.

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11. Describe how the relative rates of photosynthesis and cellular respiration change through the day. Use the data to describe how you came to this conclusion.

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12. Could the pattern you see in the figure you drew for question 10 explain why some people call rain forests the lungs of the planet?

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Data Table 3 uses the data in Table 2 to estimate the total amount of carbon dioxide (in mols) produced or consumed during two-hour time blocks for a kilometer of rain forest.

**Data Table 3. Carbon dioxide production (positive numbers) or consumption (negative numbers) during two-hour time blocks in a tropical forest in Costa Rica**

TIME OF DAY	CARBON DIOXIDE PRODUCTION OR CONSUMPTION (mol CO <sub>2</sub> /km <sup>2</sup> )
0000–0200	50400
0200–0400	54000
0400–0600	39600
0600–0800	36000
0800–1000	36000
1000–1200	–115200
1200–1400	–115200
1400–1600	–90000
1600–1800	–36000
1800–2000	0
2000–2200	36000
2200–0000	46800

Name: \_\_\_\_\_

Date: \_\_\_\_\_

13. Use the data in Data Table 3 to calculate the net production or consumption of carbon dioxide during the course of a day in a square kilometer of rain forest. (Hint: add all the numbers up.) Use this answer to argue whether the forest is a producer or consumer of oxygen.

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Are rain forests the lungs of the planet because they produce most of our oxygen? This isn't a simple question, so we will look at two measures that will help us find an answer. The first measure we'll consider is the net primary productivity (NPP) of different biomes on land. Net primary productivity is a measure of how much carbon is incorporated into plants during the year, so it tells us how much more photosynthesis than cellular respiration occurs in plants within a biome. In other words, NPP is total photosynthesis minus total cellular respiration for a biome.

The higher the NPP, the more oxygen a biome produces. NPP can be calculated by estimating the total growth of plants within a biome.

Once we see how much rainforests contribute to NPP on land, we will investigate the relative contributions of producers in the oceans and those on land.

14. Complete Data Table 4 by calculating the proportion of total global terrestrial NPP that occurs in each biome.

**Data Table 4. Rates of net primary productivity (NPP) in different biomes worldwide.**

**Negative numbers reflect carbon dioxide being consumed by plants during photosynthesis.**

BIOME	NPP (–g of C/m <sup>2</sup> per yr)	AREA COVERED WORLDWIDE (x 1 x 10 <sup>6</sup> km)	TOTAL NPP (Pg of C per yr <sup>a</sup> )	PERCENTAGE OF GLOBAL TERRESTRIAL NPP
Tropical forests	–2500	17.5	–21.9	
Temperate forests	–1550	10.4	–8.1	
Boreal forests	–380	13.7	–2.6	
Mediterranean shrublands	–1000	2.8	–1.4	
Tropical savannas and grasslands	–1080	27.6	–14.9	
Temperate	–750	15.0	–5.6	
Deserts	–250	27.7	–3.5	
Arctic tundra	–180	5.6	–0.5	
Crops	–610	13.5	–4.1	
Total	n/a			n/a
<sup>a</sup> 1 Petagram (Pg) = 1,000,000,000,000,000 g				

Name: \_\_\_\_\_

Date: \_\_\_\_\_

15. In your Evidence Notebook, draw a bar graph showing the percent of terrestrial NPP of each land biome.

Plants on land are not the only organisms that photosynthesize. Phytoplankton in the oceans could also be a big part of global oxygen production. To compare

the amount of oxygen that might be produced by different ecosystems, we want to be able to measure not just NPP, but the total amount of photosynthesis and the total amount of cellular respiration within the ecosystem. This value of total respiration and decomposition accounts for all organisms—including animals

Gross primary productivity is measured by the total amount of carbon (from carbon dioxide) that is taken up by photosynthesis. (A negative number means carbon is being taken out of the atmosphere.)

If we subtract the total amount of carbon that is released into the atmosphere from decomposition and cellular respiration, we can figure out how much carbon is being taken up in oceans and on land.

Data Table 5 below presents data on the amount of photosynthesis, cellular respiration, and decomposition that occurs on land and in the oceans. Remember, the more carbon dioxide that is taken up, the more oxygen that is produced. Table 5 shows total global carbon uptake and release typical in the 1990s. The abbreviation Gt stands for gigatonne, which is equivalent to one billion metric tons (tonnes). One major source of carbon that is not represented in this table is release from the burning of fossil fuels (approximately 6.3 Gt/year).

**Data Table 5. Worldwide primary productivity, cellular respiration, and carbon uptake in the 1990s. Negative numbers indicate that carbon dioxide is being taken up and positive numbers indicate that carbon dioxide is being released into the atmosphere.**

	GROSS PRIMARY PRODUCTION (Gt C/yr)	TOTAL RESPIRATION AND DECOMPOSITION (Gt C/Yr)	NET PRODUCTION OF CARBON (Gt C/yr)
Terrestrial	-120	118.6	-1.4
Ocean	-92.5	90.8	-1.7

16. Based on the data in Table 5, compare the amount of oxygen that is being released (accounting for the amount used) by producers in the oceans versus producers on land.

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## EXPLAIN

We are almost ready to deal with the “lungs of the planet” question. In addition to the data you have analyzed, consider the following information:

- CO<sub>2</sub> uptake is about equal to O<sub>2</sub> production.
- The concentration of CO<sub>2</sub> in the atmosphere is approximately 390 ppm (0.039% of the atmosphere) and the concentration of O<sub>2</sub> in the atmosphere is approximately 210,000 ppm (21% of the atmosphere).
- Scientists estimate that the values of terrestrial plant uptake of CO<sub>2</sub> shown in Table 5 accounts for about 8% of the CO<sub>2</sub> in the atmosphere.

17. Based on the bulleted information above, are terrestrial plants contributing a relatively large amount of oxygen each year to the current oxygen concentration of the atmosphere?

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18. Using the graph of terrestrial NPP, carbon uptake values in Table 5, and your answer to question 17, would you call the rain forests the lungs of the planet? Explain your answer.

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19. Climate change is largely driven by increasing concentrations of carbon dioxide in the atmosphere. Carbon dioxide is a greenhouse gas, which absorbs and radiates energy as heat back to Earth. So, an increase in CO<sub>2</sub> in the atmosphere will warm Earth’s surface. Based on what you have learned in this activity, why is it important to protect tropical forests?

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20. What would happen to the amount of CO<sub>2</sub> in the atmosphere if trees were chopped down and burned (or are blown down in a hurricane) and decompose? Why? (Hint: Recall that the process of decomposition consumes oxygen and releases carbon dioxide.)

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