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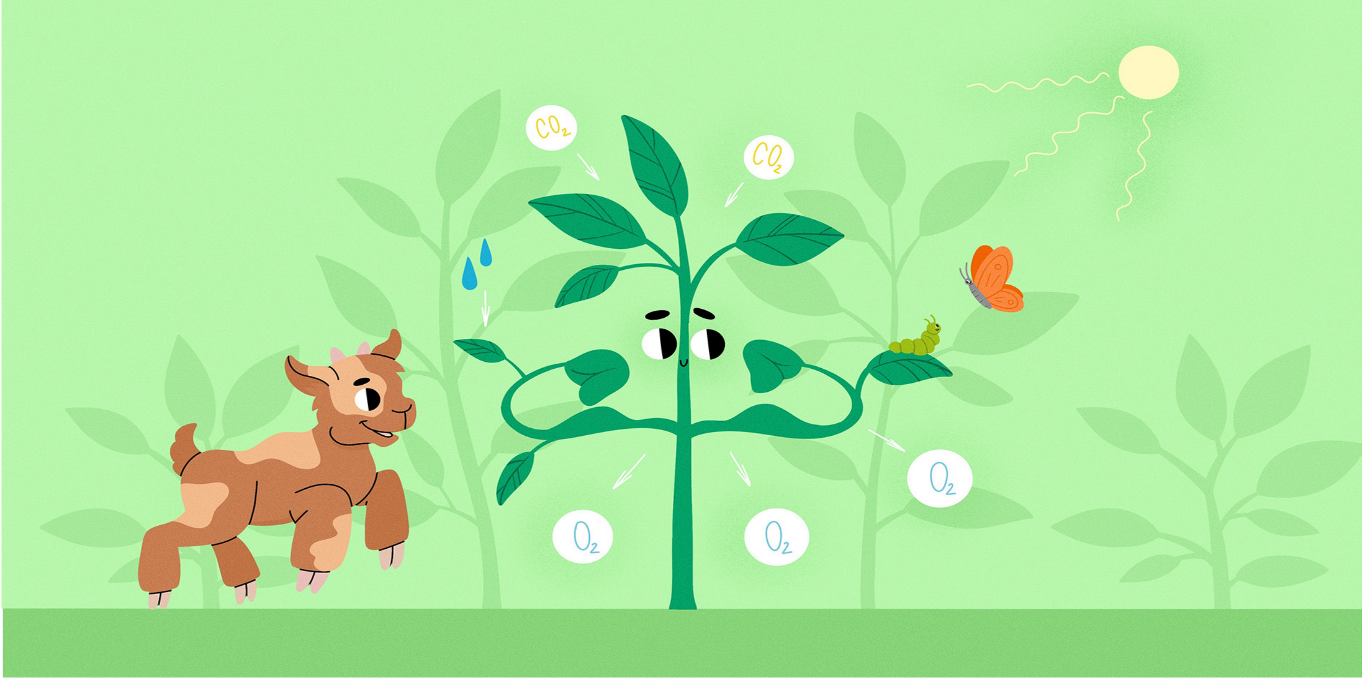

SOLAR-POWERED LIFE: HOW PLANTS AND OTHER ORGANISMS PRODUCE THEIR OWN FOOD

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YOUNG REVIEWERS:


ANAGHA
AGE: 9


ANVITHA
AGE: 12


ERIC
AGE: 11


SRINIKA
AGE: 12

Some organisms can produce their own food through a process called photosynthesis. These organisms transform light energy, carbon dioxide, and water into sugars, which allow them to grow their bodies, reproduce, and be a source of energy for other organisms. Studying photosynthesis in nature and in the laboratory has given scientists important insights into the effects of climate change on plants and other photosynthetic organisms. For example, such studies help scientists understand whether there will continue to be enough food for humans to eat as the climate changes. In this article, we discuss the importance of photosynthetic organisms; how light energy, carbon dioxide, and water are transformed into sugar during photosynthesis; the challenges that today's land plants face; and how and why scientists measure photosynthesis in plants.

SUNLIGHT AND SUGAR-MAKING

Sugars give all living organisms the energy they need to move, grow, and reproduce. Some organisms (including humans) get the sugars they need from eating food. Other organisms, called **primary producers**, do not have to eat because they can make their own sugars. Most primary producers use sunlight to combine carbon dioxide and other compounds into sugars, through a process called photosynthesis. Photosynthesis is essential for all living creatures since it takes carbon dioxide (an important greenhouse gas) out of the air, puts oxygen into the air, and makes the foods that other organisms eat.

Plants are the most famous primary producers, but did you know that plants are not the only organisms that can do photosynthesis? There are lots of other types of primary producers that are photosynthetic. The Earth formed over 4.6 billion years ago, and land plants have been around for just the last 500 million years or so. Some bacteria, called cyanobacteria, have been living in the ocean, doing photosynthesis and releasing oxygen, for 3 billion years longer than plants [1]. Other non-plant organisms, including algae, are also primary producers and do photosynthesis in lakes and oceans. All the non-plant organisms that do photosynthesis actually produce most of the oxygen that we breathe.

WHERE DOES PHOTOSYNTHESIS OCCUR?

The production of sugars by primary producers is a complex chemical process that uses sunlight, water, and carbon dioxide (Figure 1). Plants and bacteria use **chloroplasts** (small organs inside their cells and leaves) to do photosynthesis. These tiny organs have green **chlorophyll** pigments used to capture energy from sunlight and make sugars.

Photosynthesis consists of two main types of reactions: those that are dependent on light and those that are not. Light-dependent reactions are the first step in producing sugars. During this step, two pairs of chlorophyll molecules absorb light energy and transform it into chemical energy. As a result, plants generate two important molecules: **ATP** and **NAPDH**.

The light-independent reactions are also called the Calvin cycle. In these reactions, plants use the ATP and NADPH molecules created in the light-dependent reactions. ATP and NAPDH help plants turn carbon dioxide, which they take up from the air through their **stomata**, into sugars (Figure 2). The plants can then use these sugars to keep growing their roots, stems, and leaves, as well as to make flowers, fruits, and seeds. Animals and fungi also use those sugars as food when they eat the plants. So, the next time you see a plant, remember that

PRIMARY PRODUCERS

Organisms capable of doing their own food by transforming sunlight, water, minerals, and carbon dioxide into organic carbon (sugar).

CHLOROPLASTS

Small organ-like structures (organelle) found withing the plant's cell in which photosynthesis occurs.

CHLOROPHYLL

Pigment found in the chloroplast of the plant's cells in charge of absorbing blue and red light used toward sugar production.

ATP

Adenosine triphosphate, the "energy currency" of the cell. ATP is used to perform cellular reactions that require energy.

NAPDH

Nicotinamide adenine dinucleotide phosphate hydrogen, an energy-carrying molecule that provides energy for the Calvin cycle, in the form of hydrogen atoms.

STOMATA

Cell structures in leaves, composed of an opening surrounded by two guard cells, that control the exchange of gases and water with the environment.

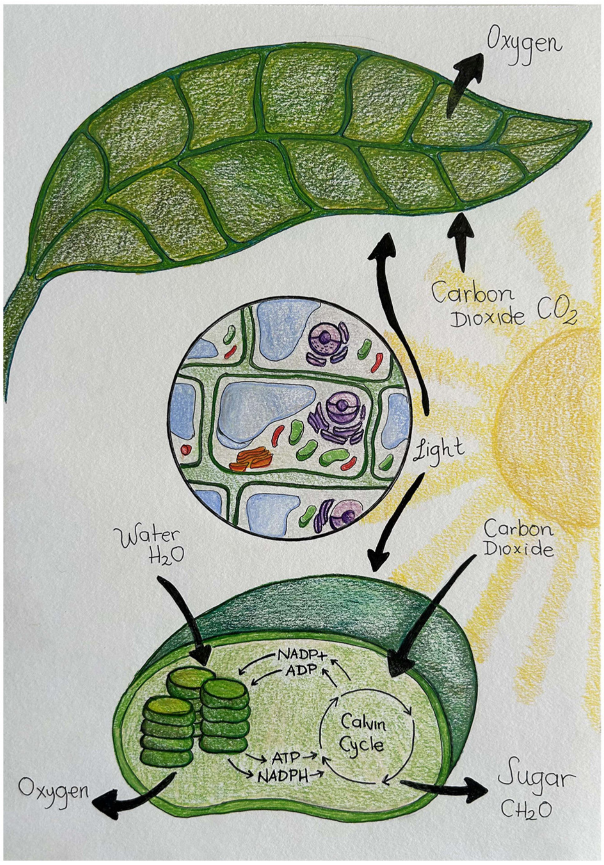

Figure 1

Figure 1

The process of photosynthesis in a plant leaf. The key ingredients are sunlight, water, and carbon dioxide. The light-dependent reactions that occur within the chloroplasts require light and result in the production of ATP and NADPH. The light-independent reactions, or Calvin cycle, occur in the inner space of the chloroplasts and result in the production of sugar (figure credit: Alejandra Castillo).

it uses solar power to produce its own food—and to make all the food that we animals eat. Thank you, plants!

TODAY'S LAND PLANTS FACE CHALLENGES

When we use fossil fuels (e.g., coal, natural gas, and oil), we increase the amount of carbon dioxide in Earth's atmosphere. You may think that more carbon dioxide would be good for plants and allow them to produce more sugar and more oxygen. Unfortunately, more carbon dioxide does not always translate into more photosynthesis. This is because plants also need lots of water to do photosynthesis. Plants get water from the soil, through their roots. This water gives hydrogen to chlorophyll, to keep the light-dependent reactions working, and it is also the source of the oxygen that plants put into the air. In addition, when plants open their stomata to take up carbon dioxide from the air, they lose a lot of water through **evapotranspiration**. In fact, on average, plants lose about 400 molecules of water for every one molecule of carbon dioxide that they get.

EVAPOTRANSPIRATION

Movement of water from Earth's surface into the atmosphere via both evaporation and transpiration (loss of water through plant leaves).

Unfortunately, increasing amounts of carbon dioxide in the air are causing climate change, which is making it hotter and causing lots of places to have less rain or longer dry seasons. Less rain and hotter

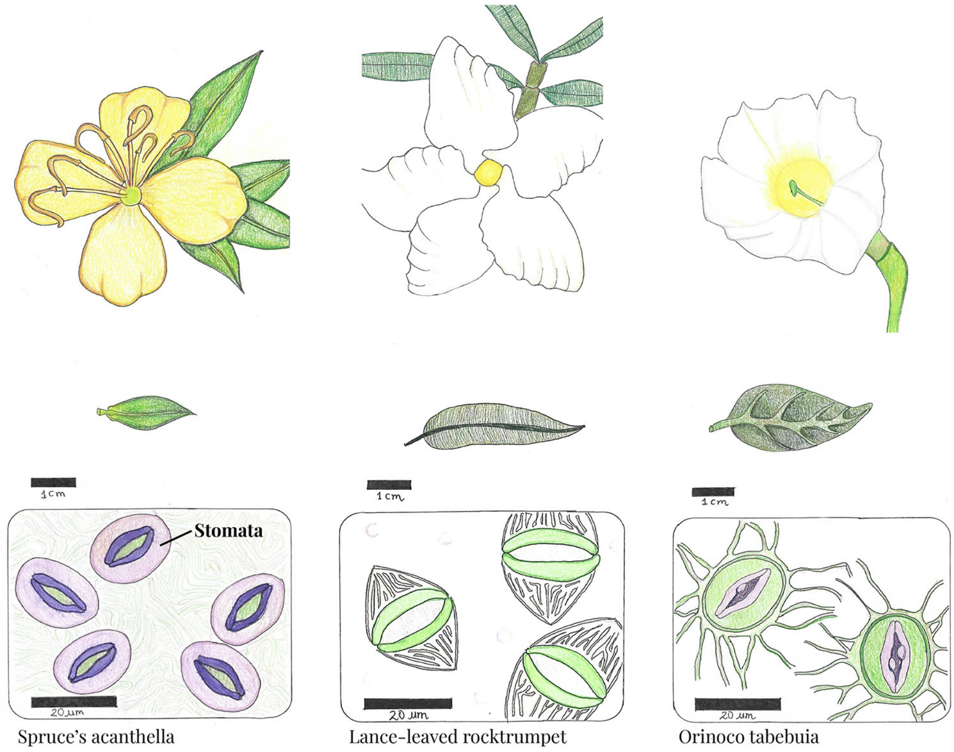

Figure 2

Figure 2

Flowers, leaves, and stomata of three plant species that grow on big tropical rock outcrops in Colombia: Spruce's acanthella **(left)**, lance-leaved rocktrumpet **(middle)**, and orinoco tabebuia **(right)**. Big leaves tend to have fewer stomata. This means that small leaves like the ones of Spruce's acanthella have a lot of small stomata, while big leaves like the ones of orinoco tabebuia have fewer stomata (figure credit: Alejandra Castillo).

temperatures mean that many plants have less water available. So, when we use fossil fuels and put more carbon dioxide into the air, we may actually be making it harder for plants to do photosynthesis. Scientists have tested this idea by growing plants in air with extra carbon dioxide. The scientists found that plants could, in fact, do more photosynthesis and grow faster *for a while* because of the extra carbon dioxide—but this boost did not last for long. Soon, the plants started growing slower or even dying because there was not enough water or nutrients in the soil to keep them alive [2].

HOW DO WE MEASURE PHOTOSYNTHESIS IN NATURE?

Scientists who study plants use very sophisticated machines called **infrared gas analyzers** (IRGAs) to measure how fast plants do photosynthesis and turn carbon dioxide into sugars (Figure 3). IRGAs detect the infrared light that is absorbed by various gases in the air. To use the IRGA, the scientists put a leaf or even a small plant inside a special airtight chamber. Then, they fill the chamber with air that has a known amount of carbon dioxide. Next, they keep measuring the amount of carbon dioxide in the chamber. If the plant is doing photosynthesis, it will take carbon dioxide out of the air, and the concentration of carbon dioxide in the chamber will decrease. The faster the plant does photosynthesis, the faster the carbon dioxide is removed from the chamber.

INFRARED GAS ANALYZER

Detectives of the infrared light that is absorbed by gases in the air. These detectives use special light sensors that measure the amount of carbon dioxide.

Figure 3

A scientist measuring the rate of photosynthesis in the leaf of a plant using an Infra-Red Gas Analyzer (IRGA; figure credit: Alejandra Castillo).

Using IRGA, scientists can also measure the concentration of water in the air inside the chamber. Remember that plants lose lots of water through evapotranspiration as they take up carbon dioxide—so the more water that gets added to the air, the faster the plant is losing water as it does photosynthesis. Some types of plants (e.g., cacti) can do lots of photosynthesis without losing much water. These plants may have special tricks or adaptations for using less water, so they are especially good at living in deserts or other dry places. Other types of plants lose lots of water when they do photosynthesis. These thirsty plants would have a hard time living in dry places, and they may have a tough time surviving if climate change continues to make our world hotter and drier.

Another thing that scientists can test with IRGA is how much light plants need to do photosynthesis [3]. They can also test how fast plants do photosynthesis with different amounts of carbon dioxide in the air, or at different temperatures [4]. These types of measurements can be slow. For example, it takes about 45 min to measure how much light a leaf needs for photosynthesis, since the scientist must expose the leaf to lots of different light levels, and they must give the plant time to adjust and relax between each treatment. Forty-five minutes might not seem like a lot, but keep in mind that some scientists need to measure photosynthesis in the middle of a wet jungle or a hot desert. Keeping the IRGA machine working for that long can be challenging, since these machines are very fragile and use lots of battery power. Scientists also do not just measure one leaf! To do a good study, they may try to measure photosynthesis on hundreds of leaves from lots of plants. This is a lot of work, but it is all worthwhile if it helps scientists understand what certain types of plants need to do photosynthesis and if these plants are in danger from climate change.

WHY DO WE NEED THIS INFORMATION?

Scientists measure photosynthesis for lots of reasons. One reason is to study the effects of climate change on how many vegetables and fruits our plants can grow [5]. For example, scientists can grow the plants people like to eat, like beans, tomatoes, carrots, or avocados, in different temperatures and with varying amounts of water. To change the temperatures, scientists can use special greenhouses to make the plants hotter. They can also give the plants all the water they need, or they can block out the rain and force plants to live with less water. Scientists can even change what time of year the plants get water. Through these clever experiments, scientists can monitor the health and photosynthesis of plants grown under differing conditions, to see if the plants will be able to keep producing our food when the climate changes. Given how valuable plants and primary producers are for our planet, this is very exciting and important research.

IN A NUTSHELL, PHOTOSYNTHESIS IS AMAZING!

Plants and other photosynthetic organisms use solar power to make their own food and, in the process, they provide us with food and oxygen, remove carbon dioxide from the air, and help protect the planet from climate change. Scientists measure photosynthesis to study how plants work and how photosynthesis may be affected by climate change. Scientists use their creativity and IRGAs to measure photosynthesis in different kinds of plants and under varying conditions. This important information will help scientists understand how plants will perform in a hotter and drier world, and if plants will be able to keep doing so many great things for humans and for all life on Earth. If you were a scientist, what plant experiments would you do?

REFERENCES

1. Sánchez-Baracaldo, P., and Cardona, T. 2020. On the origin of oxygenic photosynthesis and Cyanobacteria. *New Phytol.* 225:1440–6. doi: 10.1111/nph.16249
2. Li, F., Guo, D., Gao, X., and Zhao, X. 2021. Water deficit modulates the CO_2 fertilization effect on plant gas exchange and leaf-level water use efficiency: a meta-analysis. *Front. Plant Sci.* 12:775477. doi: 10.3389/fpls.2021.775477
3. Aragón, L., Messier, J., Atuesta-Escobar, N., and Lasso, E. 2023. Tropical shrubs living in an extreme environment show convergent ecological strategies but divergent ecophysiological strategies. *Ann. Bot.* 2023:mcad002. doi: 10.1093/aob/mcad002
4. Taylor, T. C., Smith, M. N., Slot, M., and Feeley, K. J. 2019. The capacity to emit isoprene differentiates the photosynthetic temperature responses of tropical plant species. *Plant Cell Environ.* 42:2448–57. doi: 10.1111/pce.13564

5. Tito, R., Vasconcelos, H. L., and Feeley, K. J. 2018. Global climate change increases risk of crop yield losses and food insecurity in the tropical Andes. *Glob. Change Biol.* 24:e592–602. doi: 10.1111/gcb.13959

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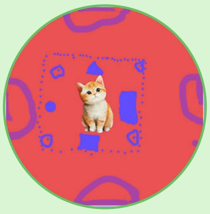
CONFLICT OF INTEREST: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

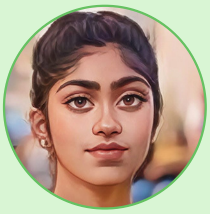
YOUNG REVIEWERS

ANAGHA, AGE: 9
I am Anagha. I love to read, draw, and dance. My favorite subjects are ELA, Math, and Science. I would like to be a Teacher in the future.

ANVITHA, AGE: 12
My name is Anvitha and I think polar bears are awesome! I also love music; dancing to it, making it or just listening to it. I enjoy learning about what is going on in the world, so I am really happy to be a young reviewer for the journal Frontiers for Young Minds.



ERIC, AGE: 11
My name is Eric, and I am Brazilian. I am 11 years old and in the sixth grade at school. I like to run and participate in sports such as swimming, capoeira, football, and biking. I also enjoy playing games, playing the violin, going to the beach, and playing with my cat, Crystal. Additionally, I have a keen interest in space and robots.



SRINIKA, AGE: 12

My name is Srinika, and I love trying new things. I love playing chess, drawing, and biking. I also love the outdoors. My favorite subjects are math and science. I hope, that someday in the future, I become a doctor.

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