# Limiting factors: photosynthesis

FizziQ activity · High school · 50 min

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High school students vary light, temperature or wavelength and follow $CO_2$ consumption with an SCD40 sensor. FizziQ Connect logs the data on smartphone or tablet.

## Learning objectives

- Design an experimental protocol with identified variables (independent, dependent, controlled)
- Formulate a testable hypothesis about the influence of a factor on photosynthesis
- Perform multiple measurements under controlled conditions
- Calculate and compare $CO_2$ consumption rates under different conditions
- Draw conclusions based on data and relate them to biological mechanisms

## Instruments and sensors

$CO_2$ meter · $O_2$ meter (optional) · SCD40 sensor ($CO_2$, temperature, humidity) · $O_2$ sensor

## Materials

- Smartphone or tablet with FizziQ Connect
- SCD40 sensor ($CO_2$, temperature, humidity)
- $O_2$ sensor (optional)
- M5 Stack module
- Sealed transparent chamber
- Fresh leaves
- Light sources of varying intensity and color
- Thermometer and water bath
- Note: the protocol remains adaptable to any comparable gas concentration measurement tool.

## Protocol

1. Choose the factor you wish to study: light intensity, light color, temperature, or plant type.
2. Identify the variables: the independent variable (the factor you vary), the dependent variable ($CO_2$ consumption rate), and the controlled variables (everything else held constant).
3. Prepare the basic setup: connect the SCD40 sensor to the M5 Stack module, connect FizziQ Connect, and verify the readings.
4. Perform a first control measurement: place the plants in the sealed chamber in daylight for 10 minutes. Calculate the $CO_2$ consumption rate (slope of the $CO_2$ curve).
5. Modify the chosen factor for the second condition. For example: reduce light intensity (move the lamp farther or use a filter).
6. Perform the second measurement under the same conditions (same duration, same plant volume, same chamber), changing only the tested factor.
7. Repeat for at least a third condition (for example: bright, medium, and dim light; or 5°C, 20°C, 35°C).
8. For each condition, calculate the slope of the $CO_2(t)$ curve during the linear phase. This slope represents the $CO_2$ consumption rate.
9. Plot a summary graph: $CO_2$ consumption rate versus the studied factor.
10. Compare your results with your initial hypothesis. Conclude on the influence of the factor and propose explanations based on the underlying biology.

## Expected results

Results depend on the factor studied. For light intensity: $CO_2$ consumption rate increases with intensity up to a plateau (pigment saturation). For light color: red and blue light give the highest rates, green the lowest. For temperature: rate increases up to 25-35°C then drops. For plant type: C4 plants (corn) are faster than C3 plants (spinach) at high light and temperature.

## Questions

- Why is photosynthesis more efficient under red and blue light than under green light?
- How does temperature influence enzyme activity, and why is there an optimum?
- What is the light compensation point and why does it matter for plant ecology?
- How would increasing $CO_2$ concentration affect the photosynthesis rate?
- Why is it important to vary only one factor at a time?
- How do your results relate to the global carbon cycle?

## Going further

- Study the effect of monochromatic light using red, blue, and green filters to relate results to the chlorophyll absorption spectrum
- Use aquatic plants (Elodea) and count $O_2$ bubbles as an alternative measure of photosynthesis rate
- Compare sun leaves and shade leaves from the same tree species
- Investigate the effect of $CO_2$ concentration by adding baking soda to the chamber
- Study the combined effect of two factors (e.g., light and temperature) and create a 2D response surface