Section 5.4: Alternative Mechanisms of Carbon Fixation

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1. Plants, especially those living in hot dry environments, sometimes have difficulty getting all the CO_2 they need to photosynthesize efficiently because they need to close their stomata to conserve water. Since gas exchange occurs through the stomata, less CO_2 can enter the leaf when the stomata are closed, or even partially closed. In addition, the solubility of CO_2 decreases as temperature increases (the Calvin cycle occurs in the aqueous stroma) and that also decreases CO_2 available to the plant.

2. None of these grasses have succulent leaves or thick stems, so they are probably not CAM plants. Corn can grow well in hot and/or relatively dry conditions, so it is a C_4 plant. Wheat is a major crop in Canada, which has a cool temperate environment, so we would expect wheat to be a C_3 plant. Rice grows in wet rice paddies and C_3 plants are better suited for moist conditions, so it is probably a C_3 plant.

3. PEP carboxylase does a better job than rubisco at fixing CO_2 in C_4 plants because PEP carboxylase does not have an affinity for O_2 like rubisco has; therefore, there is no loss of efficiency due to photorespiration as with rubisco. PEP carboxylase works better than rubisco in an oxygen-rich environment.

4. The grass might not be growing quickly on a hot, summer day because the grass may have all its stomata closed to conserve water. If this is the case, photosynthesis will be operating very slowly and energy may be wasted on photorespiration so the grass will not be growing actively.

5. (a) C_4 plants will grow more efficiently in a hot, wet tropical environment. The high temperature requires protection from photorespiration, but there is no need to conserve water during the day.

(b) CAM plants will grow more efficiently in an environment with extremely hot days and cool nights. They have adapted for water conservation during the day by only opening their stomata at night.

(c) C_3 plants will grow more efficiently in a cool, damp environment. Photorespiration and water loss are not a concern, so using C_3 only saves on ATP consumption.

(d) C_4 plants will grow more efficiently in an environment with a moderate climate but nutrient-poor soil. These plants use less rubisco, so they have a lower nitrogen demand. (Nitrogen is a key element in amino acids and proteins.).

6. Answers may vary. Sample answers include:

- C_3: 85% of plant species, including cereal grains (wheat, rice, barley, oats), peanuts, cotton, sugar beets, tobacco, spinach, soybeans, most trees, most lawn grasses
- C_4: corn, many summer annuals, sugarcane, millet, many tropical grasses
- CAM: succulents such as cactuses, agaves; many orchids; Spanish moss; some ferns; pineapple

7. (a) Yes, placing a clear plastic bag over houseplants would provide evidence of the type of carbon fixation strategy used by each plant. One would expect CAM plants to have little or no condensation during the day, but possibly a small amount during the night. You would expect C_3 and C_4 plants to have condensation during the day, but less during the night. Because C_4 plants are more efficient, they have fewer and smaller stomatal openings; therefore, you would expect there to be less condensation with the C_4 plants than with the C_3 plants.

(b) Yes, you would expect different results if the experiment was conducted during the day or at night. You could determine whether a plant was a C_3/C_4 or a CAM plant. CAM plants would have little or no condensation during the day, but possibly a small amount during the night. C_3/C_4 plants would have more condensation during the day.

8. Scientists are interested in genetically modifying plants to change their carbon fixation pathways to alter how well they will grow under different environmental conditions. For example, you could develop a wheat plant that thrives in the tropics or a corn plant that grows well in cool weather.
9. You would expect an aloe vera plant to be a CAM plant, since it is a succulent plant.