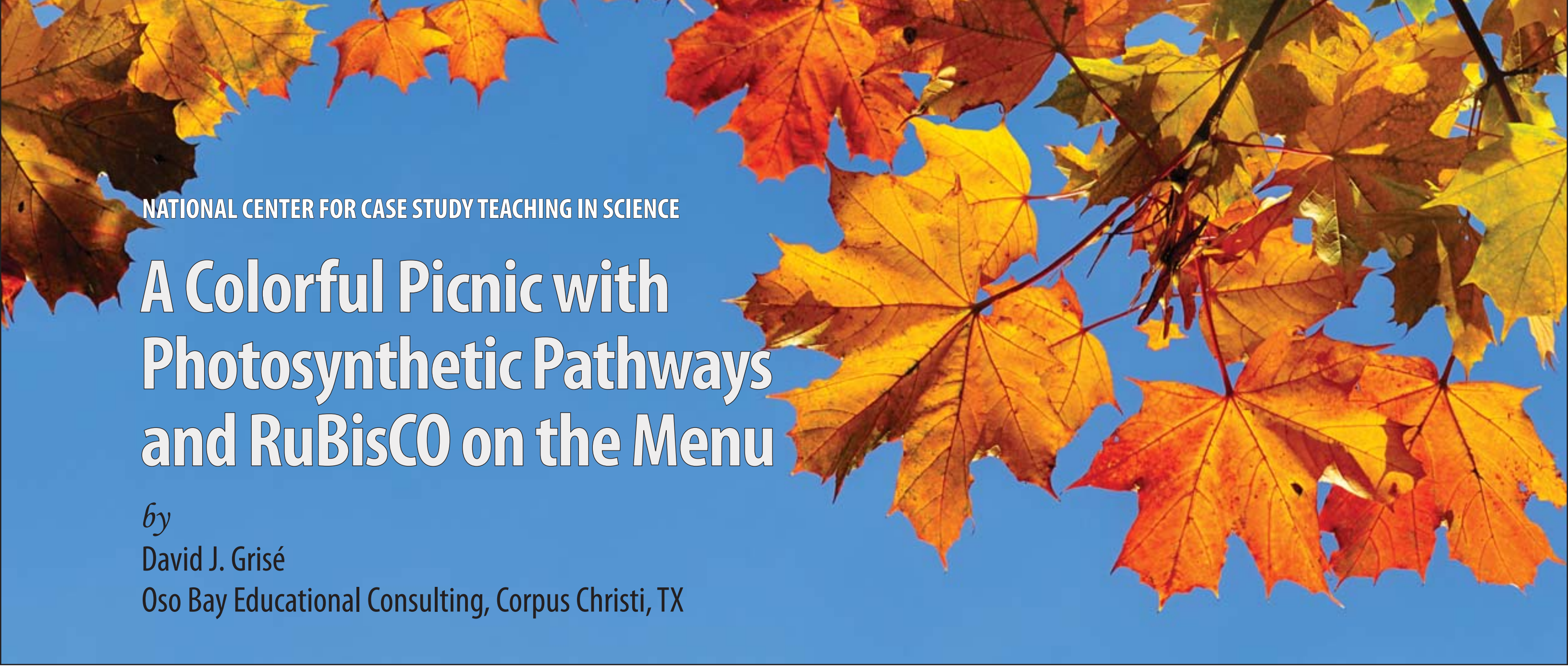

NATIONAL CENTER FOR CASE STUDY TEACHING IN SCIENCE

A Colorful Picnic with Photosynthetic Pathways and RuBisCO on the Menu

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Part I – Absorbtion and Reflection

"Hey Ben, this looks like a nice place to have our lunch."

"I guess so Abbie, but anywhere would be a good place to have lunch on such a perfect day."

"The fall colors are just stunning. The trees didn't turn these colors when we lived in Texas."

"Not only that," agreed Ben, "but when we lived in Corpus Christi, Texas, we didn't have anything that you could call fall or winter. The trees were green most all year. Rhode Island sure is a different climate than what we had when we were undergraduates in Corpus Christi."

"Ben, get out the food! I'm hungry! While you do that I'm going to text Cori a picture of this gorgeous orange Sugar Maple."

"Alright Abbie, but I kind of like those bright red Red Maples over there also. We must be at the peak of fall color now."

"Just got a text from Cori," said Abbie. "She said that trees in North Carolina are still green. She asked if we remember when we learned why plants are green when we were in intro bio."

"Not only do I remember why and the question on the exam, but I also remember when our instructor dressed up as RuBisCO for Halloween! I also remember later, when you and Cori were assistants for the class, that you two dressed up as homologous chromosomes."

"That was fun! We even figured out how to show crossing over in meiosis. I use some of the activities I did for the intro bio class as a graduate TA now," said Abbie.

Questions

1. Why are plant leaves green?
2. Are some flowering plants normally a color other than green? If so, do these plants contain chlorophyll?
3. Are there photosynthetic organisms that do not contain chlorophyll? If so, what are these photosynthetic organisms?
4. Do green leaves absorb the maximum amount of light? If not, what color of leaf would absorb more light?
5. What does the presence of bright red Red Maples tell you about the general weather pattern in the late summer/fall in the part of Rhode Island where Abbie and Ben are having lunch?

Part II – Atmospheric CO_2 Concentration and Temperature

"Ben, I'm going to cover the effects of atmospheric CO_2 concentrations and temperature on photosynthesis in the lab I'm teaching this week. Do you remember what we learned about atmospheric CO_2 concentrations at the time when oxygen-evolving photosynthesis became common?"

"Of course I do! Atmospheric CO_2 concentrations were above 1000 ppm, which is much higher than our current concentration of 400 ppm. I also remember that our current atmospheric CO_2 concentration is the highest CO_2 concentration there has been in the past 400,000 years."

"Very good! If I'm ever in a trivia contest, I hope you're on my side. But what do these numbers mean to plants or to us?"

"Well Abbie, I remember some of this, but because you worked with the intro bio course, you might have to help me out with the details."

"OK Ben, fair enough. Let's start with the effect of CO_2 concentrations and temperature on photosynthetic rates. Photosynthesis produces sugars, and sugars are needed for plant growth. That should mean something to the plants and to organisms such as ourselves who eat plants."

"Yes it should and I think I got this one. But can I just talk about what happens at higher temperatures for now?"

"Alright, let's keep this somewhat simple and only discuss temperatures above about 20 degrees Celsius or so for now."

"Got it, Abbie. RuBisCO, which is the enzyme that brings CO_2 into the cycle that results in sugars being made, is very efficient at high CO_2 concentrations. If there is a lot of CO_2 near RuBisCO, RuBisCO is efficient even at higher temperatures, such as those found in the tropics. Photosynthetic rates will be high at higher temperatures if there is a lot of CO_2 near R

"So Ben, when atmospheric CO_2 concentrations were above 1000 ppm, RuBisCO was rocking at high temperatures? Plants made a lot of sugars and could grow well even in higher temperatures?"

"I think so Abbie. Life was good for plants when atmospheric CO_2 concentrations were above 1000 ppm. Higher temperatures were not much of a factor in limiting photosynthetic rates. Other factors such as the amount of soil nutrients and water were more important in limiting photosynthetic rates."

"That's good enough, but what about the effect of higher temperature at lower CO_2 levels?"

"I'll give that a try. At lower CO_2 concentrations, RuBisCO becomes less efficient than at higher temperatures because it starts to use oxygen rather than CO_2 as a substrate. Using O_2 rather than CO_2 is called photorespiration, which is disaster for the plant. The plant has lost carbon and needs to spend energy to recover from this

Figure 1. Red Maple tree.

mess. Photosynthetic rates, and growth, would be lower at higher temperatures and lower atmospheric CO_2 concentrations."

"What do you mean by lower atmospheric CO_2 concentrations?" asked Abbie.

"Well Abbie, there is a slight negative effect on photosynthetic rates with today's CO_2 concentrations, but the effect would be much larger if CO_2 concentrations were about half of today's CO_2 concentrations. Plants would be hurting at atmospheric CO_2 concentrations of about 200 ppm."

"Right—when were atmospheric CO_2 concentrations about 200 ppm?"

"Well, um, this is why Google is my friend!"

Questions

1. Have atmospheric CO_2 concentrations of about 200 ppm occurred over the past 400,000 years? (You might want to take the above advice and make Google your friend to answer this question.)
2. Why have atmospheric CO_2 concentrations fluctuated over the past 400,000 years?
3. If all other factors affecting photosynthetic rates were equal and atmospheric CO_2 concentrations were the main factor affecting photosynthetic rates, how would plant growth in an area that is about 30 degrees C in the daytime have changed over the course of the past 400,000 years?
4. If plants were able to respond in any possible way, what could plants have done to make plant productivity higher or at least less variable over the past 400,000 year time period?

Part III – C_3 and C_4 Pathways

"Ben, we need to do this more often! That was a great lunch in a perfect location. Because these trees are shutting down for the upcoming winter, I guess they won't be taking up CO_2 until they put out leaves in the spring. I remember that graph of current CO_2 concentrations measured at Mauna Loa in Hawaii that shows CO_2 concentrations increasing a little during the winter and decreasing a little during the summer."

"I remember that too, Abbie, and I also remember that as for most plants, the trees around us here use the C_3 pathway. Did we have anything for lunch that used the C_4 pathway?"

"Yes, sugar cane and corn are C_4 plants, so anything made with sugar from sugar cane or with high fructose corn syrup used a product from a C_4 plant."

"That's what I thought. I really enjoyed the corn that we bought at the farmers' market in August and September. I'm not used to having to wait a while for the warm weather to come for the C_4 corn to do well, but it was worth waiting for."

"Cori told me that her CO_2 control system is working well, so she will be able to do her project looking at the effect of CO_2 concentrations on marine organisms. Do you remember how atmospheric CO_2 concentrations and temperature affect plants using the C_3 and C_4 pathways?"

"Um, well Abbie, I might need some help again from Google on this one."

Questions

1. Why couldn't Abbie and Ben buy locally grown corn in May or June in Rhode Island?
2. Would Cori have to wait until August to buy locally grown corn in North Carolina? How about a person living in Central or South Texas?
3. Some grass species use the C_3 photosynthetic pathway and other grass species use the C_4 photosynthetic pathway. As you move from North Dakota to Texas, explain why you think the percentage of grass species using the C_4 photosynthetic pathway would increase, decrease, or stay the same.
4. What properties of C_3 and C_4 photosynthetic pathways explain your answer to Question 3?

Part IV – CAM Pathway

"Abbie, you were in Baja California recently when you were on that cruise to collect deep sea samples for your research, right? What photosynthetic pathway were the plants in that area using?"

"I sure didn't see trees like we have in Rhode Island in Baja California because I was in the Sonoran Desert. I did see plants that use the C_3 and C_4 photosynthetic pathways, but they had major modifications, such as very small leaves or sunken stomates to reduce water loss. Most of the plants in that area and other arid areas use the CAM photosynthetic pathway."

"I remember that one Abbie! I also remember the intro bio exam question about plants using the CAM photosynthetic pathway. The professor asked which photosynthetic pathway a plant growing on power lines in Central Texas would be using."

"I think he also had something in the question about the plant not having roots that reach the ground."

"I think so. The plant would only get water when it rained. A power line would be a very arid environment!"

"Do you remember why the plants using the CAM photosynthetic pathway are so good at conserving water?"

Questions

1. Why are plants using the CAM photosynthetic pathway so good at conserving water?
2. Plants using the CAM pathway occur in many locations but are most common in very arid locations, such as deserts. What deserts occur in North America and where are these deserts located?