CHAPTER 8 PHOTOSYNTHESIS

Scientific Skills Exercise

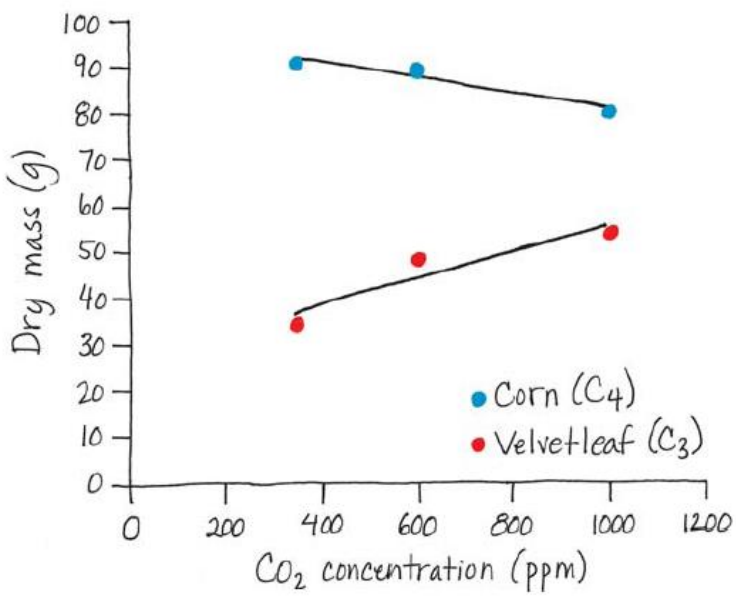
Teaching objective: The primary objective of this exercise is to give students practice in working with scatter plots and regression lines. Students are asked to describe trends shown by the regression lines, to use the regression lines to estimate values, and to calculate the percentage change of values. The student is further asked to consider the implications of the trends expressed by the regression lines.

Teaching tips: In plotting data in the scatter plot, students may wish to connect the data points. However, because the objective is to determine trends rather than to see the rate of change between each individual point, regression lines should be used. Students can try "eyeballing" a line, and then may want to check it by using Excel. They can input data into cells using the tools within Excel to plot the data and insert regression lines into their scatter plot. Tutorials for graphing in Excel can be found online. This exercise has been simplified in order to teach about regression lines. In actuality, a scientist would draw a regression line for a set of raw data points, rather than points representing averaged data.

Answers:

1. (a) The researchers intentionally varied the levels of CO_2 concentration. Therefore, CO_2 concentration is the independent variable and should go on the *x*-axis. The researchers measured the dry mass of corn and velvetleaf plants, so mass is the dependent variable and should go on the *y*-axis. (b) See the scatter plot in answer #2.

2.



3. (a) As shown by the regression lines in the scatter plot, the dry mass of corn decreased with increasing concentrations of CO_2. In contrast, increasing concentrations of CO_2 produced a marked increase in the dry mass of velvetleaf as compared to the decrease in the mass of corn. (b) Because velvetleaf is invasive to cornfields, one would expect that velvetleaf would compete with corn for water and nutrients, and therefore would negatively impact the productivity of corn plants, reducing crop yield.

4. (a) At 390 ppm CO_2, the average dry mass of a corn plant is approximately 91 g, and velvetleaf is about 38 g. At 800 ppm CO_2, the average dry mass of a corn plant would be approximately 84 g, and velvetleaf would be about 50 g. (b) At a CO_2 concentration level of 800 ppm, the dry mass of corn would decrease by about 8% [(84 g - 91 g)/91 g x 100]. For velvetleaf, the dry mass would increase by about 32% [(50 g - 38 g)/38 g x 100]. (c) These results support the conclusion from other experiments that C_3 plants grow better under increased CO_2 concentration than C_4 plants because velvetleaf, a C_3 plant, grew better at higher CO_2 levels than corn, a C_4 plant.

Interpret the Data

Figure 8.9 About 400–450 nm and 670–680 nm drive the highest rates of photosynthesis. (The first peak of the graph in (b) is quite broad.)

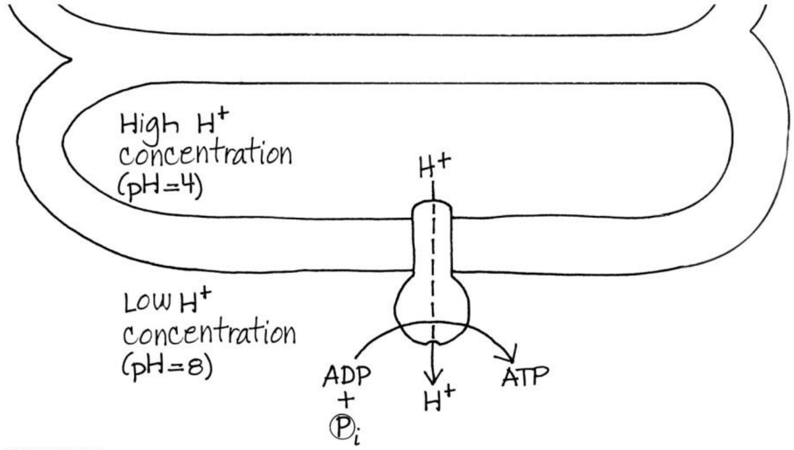
Suggested Answers for End-of-Chapter Essay Questions

See the general information on grading short-answer essays and a suggested rubric at the beginning of this document.

9. Science, Technology, and Society

Trees in tropical rain forests carry out photosynthesis, fixing CO_2 as sugar and storing carbon as they synthesize new biomass. However, trees also respire, using sugar as an energy source and releasing CO_2. While photosynthesis takes place in green leaves, respiration takes place throughout the tree, in its leaves, stems, branches, and roots. Thus, living trees are not only sinks for storing CO_2, but also sources for the release of CO_2. In addition, when a tree dies or its leaves are eaten by an herbivore, microbes or animals digest its biomass and the sugars are broken down by respiration to release CO_2. Furthermore, mass cutting and burning of forests adds significantly greater amounts of CO_2 to the atmosphere, not offset in any way by the CO_2 absorption that a living tree would be carrying out. (So the net result of cutting and burning forests is to increase the atmospheric CO_2.)

10. Draw It



The ATP would end up outside the thylakoid. The thylakoids were able to make ATP in the dark because the researchers set up an artificial proton concentration gradient across the thylakoid membrane; thus, the light reactions were not necessary to establish the H^+ gradient required for ATP synthesis by ATP synthase.

11. Focus on Evolution

Because the "ancestor" of the chloroplast was a photosynthetic prokaryotic cell according to the endosymbiont theory, you would predict that the sequences of chloroplast DNA for ribosomal RNAs in a chloroplast would be more similar to those of a photosynthetic prokaryote than to those in the nucleus of a plant cell. If this prediction is correct, it adds to the considerable body of evidence supporting the endosymbiont theory and tells us that photosynthesis first evolved in prokaryotes, and at least one eukaryotic cell may have taken up a photosynthetic prokaryote, becoming the ancestor of eukaryotic cells that contain chloroplasts. (In fact, when genes encoding ribosomal RNAs are sequenced, the chloroplast's ribosomal RNA genes are much more similar to those from photosynthetic prokaryotic species than to those from the nuclei of plant cells.)

12. Focus on Evolution

Assuming that modern soybeans are the result of breeding programs meant to maximize the size (mass) of the harvested soybeans, and assuming that soybean mass is due mostly to stored carbohydrate (or matter ultimately derived from carbohydrate), it would seem logical that crop scientists would have selected strains with reduced levels of photorespiration. This means that the wild relatives of modern soybeans would be expected to have even higher levels of photorespiration than 50%.

13. Focus on Energy and Matter

Sample key points:

- The light reactions take place in the thylakoids, where photosystems and electron transport chains are embedded in membranes that enclose the thylakoid space.
- The energy of light is used to pump electrons from water through photosystem II, an electron transport chain, and photosystem I to NADPH.

- In redox reactions in the electron transport chain, protons are pumped into the thylakoid space. ATP synthase uses this proton-motive force to make ATP.
- The Calvin cycle, which occurs in the stroma, uses the energy of ATP and the reducing power of NADPH produced by the light reactions to reduce CO_2 to sugar.
- The three stages of the Calvin cycle are carbon fixation (using rubisco to attach CO_2 to RuBP), reduction (using ATP and electrons from NADPH), and regeneration of the CO_2 accepter (using energy from ATP). The three-carbon sugar, G3P, exits the cycle and is converted to glucose and other organic molecules.

Sample top-scoring answer:
The energy transformations of photosynthesis take place in chloroplasts. The light reactions occur in the thylakoids, where photosystems containing light-harvesting complexes of pigment molecules, a reaction-center chlorophyll *a*, and a primary electron acceptor are embedded. When a pigment absorbs a photon, an electron is boosted to a higher-energy state. The energy of light is used to pump electrons from water through photosystem II, an electron transport chain, and photosystem I to NADPH. During energy-releasing redox reactions in the electron transport chain, protons are pumped into the thylakoid space. ATP synthase uses this proton-motive force to make ATP. The Calvin cycle occurs in the stroma. CO_2 is fixed into organic compounds, which are reduced using the energy of ATP and electrons from NADPH. The three-carbon sugar G3P is produced and can be converted to sugars and other organic molecules, ultimately providing the chemical energy and carbon source for all of life.

14. Synthesize Your Knowledge
This green alga is photosynthetic, so it must have chlorophyll, which appears green. However, in addition to chlorophyll, it must have accessory pigments that absorb a different wavelength, including one at high levels that appears reddish pink in visible light. Given that UV light levels are so high in the locations where these algae are located, this might be a carotenoid pigment that has a photoprotective function. (In fact, this is one of the carotenoid pigments that has been proposed to provide photoprotection, consistent with its high levels in these algal cells. Carotenoids and other accessory pigments are also responsible for the brilliant reds, oranges, and yellows of fall foliage on deciduous trees. In the summer, these carotenoids and accessory pigments are at lower levels than the chlorophyll, and their colors are revealed only in the fall when leaves stop photosynthesizing and the chlorophyll is broken down.)