Steps to Sustainability
Part 37 of a Series:
Photosynthesis

By Richard W. Franke
Professor Emeritus of Anthropology: Montclair State University, New Jersey
Resident of Ecovillage at Ithaca;

This is the latest installment in our Signs of Sustainability series, organized by Sustainable Tompkins. Visit them online at www.sustainabletompkins.org.

We meat eaters often forget that when we eat animal flesh we actually eat plants but in a most inefficient way. The animals we consume depend themselves on plants but are able to capture only about 10% of plant biomass for growth and/or tissue replacement. Put another way, it takes about 10 pounds of grain to produce one pound of beef. This is known in ecology as the "10% rule" (Uhl 2004:44 – 47).

Fortunately, the inefficiencies described by the 10% rule do not prevent earth's plant and animal species from thriving. Our sun sends out daily 20 billion tons of photons as part of its solar wind (Swimme and Berry 1992:65). A tiny portion of this enormous energy blast is captured by two green food producers – certain of the phytoplankton in the oceans and the green plant leaves on land. This process is called photosynthesis – from the Greek photo or "light," and "synthesis," or "putting together."

The secret of this amazing solar energy capture is the chlorophyll molecule. This molecule contains 137 atoms, one of them a magnesium atom surrounded by a ring of 4 nitrogen, 5 oxygen atoms and an extended tail of 55 carbon and 72 hydrogen atoms somewhat interwoven. The overall shape can be compared to a tadpole, or perhaps a stemmed champagne glass (Answers.com).

Exactly how the chlorophyll molecule snags photons – particles of light traveling at the speed of light – is not well understood. The chlorophyll molecule, may be rather ancient, appearing possibly about 3.9 billion years ago, a little after the first living cells developed around 4 billion years back (Swimme and Berry 1992:270). Of course, 900 million years IS a fair amount of time, even in evolutionary terms.

The overall process of photosynthesis – beyond "simply" catching photons – is a little less mysterious but fairly complex. The light energy of the photons is channeled to split water into its chemical components: hydrogen and oxygen. The hydrogen is then applied to a second process where the plant uses CO_2 to produce glucose, a sugar the plant can use to store energy. The oxygen (the O in H_2O or water) is sent off as a byproduct (Teacher's Pet video).

Most or perhaps all biological and chemical processes on earth are influenced by temperature. How is global warming impacting photosynthesis and thereby the world's food supply?

Scientists are only at the beginning of understanding the complex relationship between temperature and photosynthesis. Like many phenomena in nature, photosynthesis appears to follow a common response curve in the shape of an upside-down "U." At least some current food crops are near the top of the U – a location labeled their "thermal optimum." This implies that additional heat from global warming could tip them over the top of the U and actually lead to output declines. One study in India, published in 2001, found that a 1 degree increase in average temperatures had no effect on yields, but a 2-degree Celsius (3.6 degrees Fahrenheit) temperature increase led to a 8.5 percent to 38 percent decline in irrigated wheat output (Kumar and Parikh, cited in Brown 2004:69). An Ohio study from 1999 found that photosynthesis in plants generally increases to 20 degrees C (68 degrees F) then plateaus as temperature rises to 35 degrees C (95 F). At 40 C or 95F, photosynthesis ceases entirely (Wali *et al* 1999:27 as cited in Brown 2004:70). These findings suggest that global warming – while it may raise output in many areas (below or up to 95 F) but in many of the world's warmest current climates with most of the world's poorest people – it may decline.

Finally, besides its crucial role in manufacturing food for plants and thus eventually animals, photosynthesis plays a large role in maintaining (and possibly in creating) the balance of gases in the earth's atmosphere – especially its oxygen content. As put by physicist Fritjof Capra (1996:178), "By blending water and minerals from below with sunlight and CO_2 from above, green plants link the earth and the sky." This linkage and its implications will be the subject of a future "Steps to Sustainability" essay.

681 words

Richard W. Franke writes about the history of sustainability. He is professor emeritus of anthropology at Montclair State University and a resident of Ecovillage at Ithaca. To access all of Franke's Steps to Sustainability Essays, go to https://msuweb.montclair.edu/~franker/FrankeTompkinsWeekly.htm

****

Sources:

Answers.com
https://www.answers.com/Q/How_many_atoms_make_up_a_chlorophyll_molecule

Brown, Lester. 2009. *Plan B 4.0: Mobilizing to Save Civilization*. Earth Policy Institute. New York: W. W. Norton and Company, Inc. See the two citations from this book below under Kavi Kumar and Wali *et al.*

Capra, Fritjof. 1996. *The Web of Life*. New York: Doubleday Anchor Books. Quote is from page 178.

Kavi Kumar, K. S. and Jyoti Parikh. 2001. Socio-economic Impacts of Climate change on Indian Agriculture. *International Review for Environmental Strategies* 2(2). Pp. 277 – 293. This source is cited in Lester Brown (see above), page 69. The part cited is from page 287 of the original source. We used a more conservative figure because it appears that Brown confused two measurements and made the declines appear greater than they were reported in the cited paper because his citation ignores the confounding positive effects of a phenomenon called CO_2 fertilization.

Swimme, Brian, and Thomas Berry. 1992. *The Universe Story: From the Primordial Flaring Forth to the Ecozoic Era – A Celebration of the Unfolding of the Cosmos*. New York: HarperSanFrancisco.

Teacher's Pet. Video showing simple stages of photosynthesis. https://www.youtube.com/watch?v=iXY6J3nMjR4

Uhl, Christopher. 2004. *Developing Ecological Consciousness: Path to a Sustainable World*. Lanham, Maryland: Rowman and Littlefield Publishers, Inc.

Wali, Mohan K., Fatih Evrendilek, Tristram O. West, Stephen E. Watts, Devika Pant, Holly K. Gibbs, and Bobbi E. McClead. 1999. Assessing Terrestrial Ecosystem Sustainability:

Usefullness of Regional Carbon and Nitrogen Models. *Nature & Resources* 35(4) October-December. Pp. 21 – 33. This source is cited in Lester Brown (see above), page 70. The part cited is from page 27 of the original source.