exposure to organochlorine (OC) compounds. Such speculation is not unfounded, because of the well-known immunotoxic effects of PCBs in laboratory animals, and indeed, a subsequent experiment showed that harbor seals fed market fish differing in a variety of OC pesticides and metabolites, PCBs, and other contaminants exhibited suppressed cellular immunity (*2*). However, no compounds were administered in isolation to pinpoint PCBs specifically, and other research does not support a causal relation with the incident.

One study that examined concentrations of PCBs in tissues of harbor seals that survived the epidemic in comparison with those that succumbed stated, "data are not sufficient to conclude that there was a direct link between mortality from PDV infection and OC contamination" (*3*). Another study that examined several factors, including OCs in tissues of seals during and after the epizootic, stated that results "should not be interpreted as implying that seals with high OC levels were therefore more vulnerable to mortality from PDV" (*4*). A third study in which harbor seals were exposed to dietary PCBs and then dosed with cell-cultured PDV showed no differences in mortality or antibody production in comparison with controls, even though some dosed seals had concentrations of PCBs in tissues greater than those of wild seals killed by the epizootic (*5*).

Authorities involved in the investigation of the European harbor seal mortality event have further noted that morbilliviruses have strong immunosuppressive effects in their own right through destruction of lymphoid tissue, are highly infectious and particularly virulent in immunologically naïve populations, and that past outbreaks have repeatedly resulted in high mortality in such populations of terrestrial mammals, even before the synthesis and manufacture of PCBs (*6*).

Thomas J. O'Shea
U.S. Geological Survey, Midcontinent Ecological Science Center, Fort Collins, CO 80525–3400, USA. E-mail: Tom_O'Shea@usgs.gov

References

1. S. Kennedy *et al.*, *Nature* **335**, 404 (1988); A. D. M. E. Osterhaus and E. J. Vedder, *Nature* **335**, 20 (1988).
2. P. Ross *et al.*, *Toxicology* **112**, 157 (1996); P. S. Ross *et al.*, *Environ. Health Perspect.* **103**, 162 (1995); P. S. Ross *et al.*, *Aquat. Toxicol.* **34**, 71 (1996); R. L. De Swart *et al.*, *Ambio* **23**, 155 (1994); R. L. De Swart *et al.*, *Environ. Health Perspect.* **104** (suppl. 4), 823 (1996); R. L. De Swart *et al.*, *Vet. Immunol. Immunopathol.* **37**, 17 (1993).
3. A. J. Hall *et al.*, *Sci. Total Environ.* **115**, 145 (1992).
4. M. D. Kendall *et al.*, *Sci. Total Environ.* **115**, 133 (1992).
5. T. C. Harder *et al.*, *J. Vet. Med. B* **39**, 19 (1992).
6. S. Kennedy, *J. Cetacean Res. Manage.* **1**, 267 (1999).

To Improve Nutrition for the World's Population

The genetic engineering of rice grains to produce provitamin A (β-carotene), described by X. Ye *et al.* (Reports, 14 Jan., p. 303), is an example of the best that agricultural biotechnology can offer society. In the Perspective by Mary Lou Guerinot that accompanies Ye *et al.*'s report ("The green revolution strikes gold," p. 241), however, there are two points that are of concern.

First, Guerinot says that corn expressing *Bacillus thuringiensis* (Bt) toxin minimizes the application of insecticides for corn insect control. In fact, insecticide applications are little reduced because Bt corn only controls the European corn borer, which is a relatively minor pest on corn, especially as compared with the corn rootworm pest complex (*1, 2*). More than 90% of the insecticide applied to corn is applied for control of the rootworm complex. Furthermore, the environmental effects of Bt corn pollen on the monarch butterfly and other beneficial insects, as demonstrated by laboratory research, need to be carefully assessed under field conditions (*2*).

Second, about half the world population eats rice daily, so as Guerinot points out, adding vitamin A to rice will benefit many people, particularly those suffering vitamin A deficiency. However, looking at the broader picture, the World Health Organization recently reported that the number of malnourished is more than 3 billion people (*3*)—more than half the current world population of 6 billion.

Not mentioned by Guerinot is that per capita cereal grain production has been declining since 1984 (*4*), due in large measure to rapid population growth. This trend can be expected to continue if—as projected on the basis of the current population growth rate—the world population doubles to 12 billion in about 50 years. Other factors contributing to the decrease (grains provide about 80% of world food) are a per capita decline in cropland per person of 20% during the past decade, a 10% per capita decline in irrigation, and a 23% per capita decline in fertilizer use (*4*).

Developing more nutritious food to reduce the number of malnourished people is admirable, but in addition, strategies to increase the food supply are critically needed. These include conserving cropland resources; improving the disparity between human population numbers and their food supply; and conserving freshwater, energy, and biological resources. We need to use science and technology to improve all aspects of the global food supply.

David Pimentel[1]
Marcia Pimentel[2]
[1]College of Agriculture and Life Sciences, [2]Division of Nutritional Sciences, Cornell University, Ithaca, NY 14953-0901, USA

References

1. P. H. Schwartz and W. Klassen, in *Handbook of Pest Management in Agriculture*, D. Pimentel, Ed. (CRC Press, Boca Raton, FL, 1981), pp. 15–77.
2. D. Pimentel and P. Raven, "Commentary: Increase in genetic engineering means less reliance on chemicals," *St. Louis Post-Dispatch*, 1 August 1999, p. B3.
3. World Health Organization, *The World Food Summit: Micronutrient Malnutrition: Half of the World Affected* (press release WHO 78, Geneva World Health Organization, Geneva, 1996), pp. 1–4.
4. D. Pimentel *et al., Environ. Dev. Sustainability* 1, 19 (1999).

Response

The Pimentels raise several important issues. I used Roundup Ready soybean and Bt corn as examples of crops that benefit the farmers that grow them but, as such, do not offer added value for the people who consume them. Concerns about Bt corn will continue to be debated until lab results, such as those obtained with the monarch butterfly (*1*), and well-controlled field studies have been conducted and replicated.

Regarding how to feed the world while preventing further degradation of our environment, it is precisely the magnitude of this problem that suggests we want to take as many different approaches as possible. A more varied diet is one way to improve nutrition, but changing people's behavior takes time. In addition, water availability, soil characteristics, and climatic conditions often limit agricultural options. For these reasons, the practice of fortifying foods after harvest with essential minerals and vitamins is in wide use, for example, the addition of vitamin D to milk and various vitamins and minerals to flour (*2*). Ye *et al.*'s "golden rice," on the other hand, is an example of how we can fortify foods before harvest using transgenic technology. Unfortunately, too much of the focus has been on how such beneficial traits are introduced into crops. As the Pimentels suggest, we need to broaden the discussion and examine all aspects of global food production, not just the issues concerning transgenic crops. As responsible scientists, we must be willing to weigh the pros ands cons of various agricultural practices and to ask who ultimately benefits and who, in the end, gets to decide.

Mary Lou Guerinot
Department of Biological Sciences, Dartmouth College, Hanover, NH 03750, USA

References

1. J. E. Losey *et al., Nature* **399**, 214 (1999).
2. http://www.micronutrient.org/