LETTERS

edited by Jennifer Sills

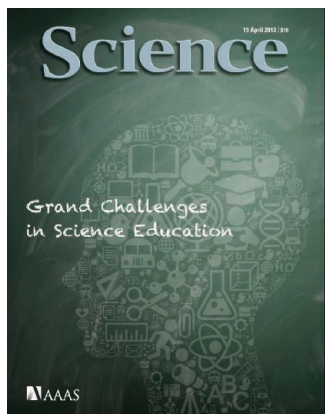
Education Guidelines Fail to Inspire

SELDOM IN THE SPECIAL SECTION ON GRAND CHALLENGES IN SCIENCE Education (19 April, p. 290) do I see the words "inspiration" or "excitement."

The News story "Transformation is possible if a university really cares" (J. Mervis, p. 292) suggests starting "by asking what the faculty member wants students to know how to do at the end of the course" and approves of applying "basic concepts to real-life situations." That is suitable for an engineering course or for basic physics, but what if your goal for nonscience students is to foster inspiration, excitement about what they have learned, and enthusiasm for supporting science by reading newspaper or magazine articles on STEM topics or by voting for candidates who demonstrate scientific experience or understanding?

The Review "Physical and virtual laboratories in science and engineering education" (T. de Jong *et al*., p. 305) acknowledges the importance of enthusiasm by suggesting that actual labs are more successful than virtual ones in creating "young people who are skillful in and enthusiastic about science," but the article is aimed at those "who view science as their future career field."

Meanwhile, the Review "Outside the pipeline: Reimagining science education for nonscientists" (N. W. Feinstein *et al*., p. 314) describes the goal of "nonscientists who can access and make sense of science relevant to their lives." I agree that we want nonscientists to "judge the credibility of scientific claims," but I contend that teaching about exciting, mind-bending, and current results can inspire students to do better in all their studies, not just those in science courses.



I suggest adding several components to the list of Next Generation Standards listed in the Venn diagram in "Opportunities and challenges in next generation standards" (E. K. Stage *et al*., Education Forum, p. 276). Students should recognize that many scientific questions are currently unsolved. They should study current trailblazers and the sequence of discovery. Courses should emphasize the importance of current research. Each topic should end with a summary of some outstanding questions.

Without context, students may leave school thinking that physical science ended with Newton and that it isn't important to support our current research efforts. They may believe that scientific problems have been solved and can all be dealt with in classroom-quality laboratories.

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Self-Medication: A Learning Process?

WE WELCOME THE RECOGNITION THAT SELF-medication in animals is widespread ("Self-medication in animals," J. C. de Roode *et al*., Perspectives, 12 April, p. 150). However, we disagree with the assumption that learning is only a valid explanation of self-medication for animals with high cognitive abilities and the ability to make "conscious decisions." This assumption underestimates the power and pervasiveness of learning.

Conditioned flavor aversions provide a flexible and effective mechanism for all animals to assemble balanced, nutritious, and safe diets and have been demonstrated in vertebrates, insects, and mollusks (*1*–*3*). Even slime molds can adjust their diets to meet specific nutritional needs (*4*). Animals continually adjust and refine their diet preferences to achieve a state of nutritional and neurological homeostasis in the face of perturbation by nutritional deficits and excesses, ingestion of toxic compounds, and also, we suggest, infection by pathogens and parasitoids (*5*). Simple animals can be guided by limited experience toward diets that achieve homeostasis through therapeutic self-medication, without cognitive awareness.

De Roode *et al*. suggest that to convincingly demonstrate that a behavior is an adaptive form of therapeutic medication, it must be shown to be relevant in the host's natural environment. Although this is necessary to demonstrate a behavior's adaptive significance, studies with novel therapeutic substances can test the flexibility of therapeutic self-medication strategies and establish the true roles of learning and of hard-wired responses. We urge researchers not to overlook the myriad fascinating processes that may underlie self-medication by any organisms.

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3. G. A. Wright *et al*., *Curr. Biol.* **20**, 2234 (2010).
4. A. Dussutour, T. Latty, M. Beekman, S. J. Simpson, *Proc. Natl. Acad. Sci. U.S.A.* **107**, 4607 (2010).
5. J. S. Forbey *et al*., *Integr. Compar. Biol.* **49**, 314 (2009).

Response

WE AGREE WITH MOORE *ET al.* that learning is widespread among organisms of vastly different cognitive abilities, providing the potential to adjust diet to combat agents of disease. However, the key word here is "potential." None of the articles cited by Moore *et al.* on insects (*1*), mollusks (*2*), or slime molds (*3*) actually presents evidence of learned medication behavior. Instead, they provide evidence that learning can adjust the behavior of organisms in response to the palatability or nutritional content of food. We certainly agree that learned responses to food quality should influence aspects of disease susceptibility in a much wider variety of organisms than only vertebrates (*4*), but evidence for it remains poor at present. Rather, our Perspective describes documented examples of medication behavior against agents of disease.

A monarch butterfly lays an egg on milkweed.

While we agree that assessing the role of learning in medication behavior is an important goal across taxa, we also suggest that an overemphasis on learning is not helpful because it can exclude important alternative mechanisms. For example, the emerging studies of medicating kin that we describe in our Perspective (*5*, *6*) are unlikely to be "guided by limited experience toward diets that achieve homeostasis." Diseased monarch butterflies preferentially oviposit on medicinal milkweed, which reduces disease in their offspring (*5*). This behavior does not involve ingestion of the plants and thus is not regulated by internal homeostasis. In general, medicating kin appears to result from innate behaviors rather than individual learning.

We also agree that artificial diets can be useful for exploring the flexibility of medication behavior. Experiments with artificial diets allow researchers to evaluate how dietary choices enable hosts to offset the costs of disease resistance (*7*, *8*). Nonetheless, the evolutionary and ecological consequences of medication that we describe in detail in our Perspective can only emerge when medication behaviors take place beyond the simplified universe of the laboratory.

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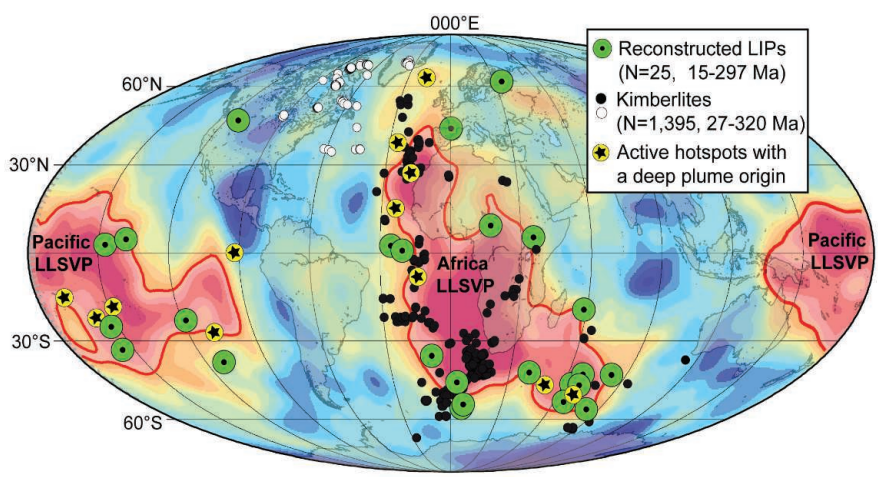
CORRECTIONS AND CLARIFICATIONS

Reports: "Enantioselective synthesis of pactamycin, a complex antitumor antibiotic" by J. T. Malinowski *et al.* (12 April, p. 180). Reference 31 should be "R. Shen, C. T. Lin, E. J. Bowman, B. J. Bowman, J. A. Porco, *Org. Lett.* **4**, 3103 (2002)." Also, this reference should be referred to in the text as "Shen *et al.*" The HTML and PDF versions online have been corrected.

News Focus: "The deep Earth machine is coming together" by R. A. Kerr (5 April, p. 22). The global map was incomplete. Due to a production error, 24 of the 25 Large Igneous Provinces (LIPs) had been deleted. In the corrected map (shown here), 23 of the 25 LIPs fall near the edges of LLSVPs—the two piles of material on the bottom of the mantle—suggesting that rising plumes connect LLSVPs to volcanic centers on the surface. The image has been corrected in the HTML and PDF versions online.



Perspectives: "The perfect hypnotic?" by E. Mignot (5 April, p. 36). Chloral hydrate, meprobamate, and barbiturates were touted as nonaddictive miracle tranquilizers at the beginning of the 20th century, not at the beginning of the 19th century as indicated in the first line of the second paragraph. The HTML and PDF versions online have been corrected.

News: "The downside of diversity" by J. Kaiser (special section of Cancer Genomics, 29 March, p. 1543). The article incorrectly attributed "punctuated evolution" to Darwin. The concept comes from the hypothesis of "punctuated equilibrium" proposed by Niles Eldredge and Stephen Jay Gould in 1972. The HTML and PDF versions online have been corrected.

News Focus: "Pollutants capture the high ground in the Himalayas" by J. Qiu (1 March, p. 1030). In the map on p. 1031, the relative locations of Mt. Everest and the Nepal Climate Observatory at Pyramid are inaccurate. The correct coordinates for Pyramid station are 27.95 N, 86.82 E, and for Mt. Everest are 27.99 N, 86.93 E.

Letters to the Editor

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