Animal Rights Review

That *Science* should have chosen Adrian R. Morrison to review the book *The Human Use of Animals: Case Studies in Ethical Choice* (*1*) (*Science*'s Compass, 8 Jan., p. 181), of which we are the co-authors, was unfortunate and unfair. Morrison has been consistent in attacking those who raise serious questions about the ethical justification of animal research. But raising such ethical questions is part of what this book is about. In his review, he is derogatory about one part of the book that describes an Animal Liberation Front (ALF) raid on the institution with which he is affiliated. Morrison's own research has been a target of ALF raids on two occasions, one closely related to the case under discussion. We therefore believe that he could not have been expected to have an unbiased opinion and should have been excluded from consideration as a reviewer.

Morrison surmises, incorrectly, that the "core belief" of some of the authors is that the "[u]se of animals to benefit humans is morally wrong." Moral condemnation of using animals to benefit humans was not among the objectives of any of the authors. Certainly Morrison should have declared his personal involvement in the raids on the University of Pennsylvania.

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References

1. F. B. Orlans, T. L. Beauchamp, R. Dresser, D. B. Morton, J. P. Gluck, *The Human Use of Animals: Case Studies in Ethical Choices* (Oxford Univ. Press, New York, 1998).

Editors' note

In the editing of Morrison's review, his statement "Brief discussion of the ethics of subsequent ALF raids of several laboratories, including mine, ends the chapter" was removed.

Perfect Mirrors, Past and Present

In their report "A dielectric omnidirectional reflector" (27 Nov., p. 1679), Yoel Fink *et al.* describe a model for an omnidirectional reflector in which it is possible to design and build mirrors that have a reflectance that is very high, regardless of the angle at which light is incident—thus the name omnidirectional mirror. These "perfect mirrors" are composed of multiple, dielectric (transparent, nonmetallic) layers that will not incur the light energy losses found in metallic mirrors and will perhaps make possible new applications. Fink *et al.* state that they are unaware of any previous knowledge of this phenomenon.

Fink *et al.* have used their expertise in analyzing the properties of crystalline materials to create a model of the optical properties of multilayer thin films as one-dimensional crystals. The nature of this model makes it straightforward for them to pose a question about omnidirectional reflectivity and from this to develop the characteristics of multilayer stacks that would have this property. They cite an example of layers of tellurium and polystyrene, which form such a mirror in the infrared (heat energy) region of the optical spectrum.

Fink *et al.* describe a novel approach to the problem of designing this kind of reflector, and its existence may certainly prompt new coating designs or applications that up to now have not been generally considered. It turns out, however, that theirs is not a unique approach to this problem, as

suggested in the Perspective "Mirror on the wall: You're omnidirectional after all?" by Jonathan P. Dowling (*Science*'s Compass, 4 Dec., p. 1841). Also, their resulting product design is not unique, although the specific choice of tellurium and polystyrene as coating materials may be.

With the use of thin-film design tools commercially available, it is relatively easy to design such "perfect" optical coatings using a broad range of coating materials. Many companies, including Optical Coating Laboratory, Inc. (OCLI), have for 30 years or more manufactured multilayer dielectric products that have the property of reflecting at all angles over a span of wavelengths, but are not necessarily sold as "omnidirectional mirrors." One such product we sell is an "infrared blocking filter" (*1*).

The optical coating market is supplied by many companies, with OCLI being among the largest. We have found that up to now there has not been a significant demand for lossless omnidirectional reflectors. Mirrors that require high reflectance at high angles of incidence are usually made using high-quality metal reflectors. The benefit of these mirrors may be to awaken interest in this issue and thereby lead to new applications for optical thin-film coatings.

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Notes

1. The OCLI Web site is at www.ocli.com.

Response

In my Perspective, I gave the impression that the idea was new in the photonic band-gap and optics communities. In fact, it was new to me and to several learned experts on one-dimensional, periodic optical structures with whom I discussed the paper at length. In particular, most of us in this field were unaware of this structure, and in fact thought its existence was impossible. Our error was to assume that a proof denying the existence of an omnidirectional photonic band gap in an infinite periodic dielectric implied the nonexistence of an omnidirectional reflector in a finite quasi-periodic structure, for reasons I outlined in my Perspective.

Nevertheless, after the publication of the report by Fink *et al.* (John D. Joannopoulos and his colleagues) and my Perspective, I received several communications from various researchers, including Seeser and Carniglia, to the effect that this idea of an omnidirectional mirror had been discussed before in various contexts. In hindsight, I could now make a case that the discovery of the existence of a one-dimensional, omnidirectional photonic band-gap reflector of sorts has been made more or less independently by (at least) the Massachusetts Institute of Technology (MIT) group of Joannopoulos; the University of Bath group of Philip Russell in the United Kingdom; the University of California, Los Angeles, group of Eli Yablonovitch; the Belarus group of Sergey Gaponenko; and a thin-film computer design program at the OCLI laboratory of Seeser.

To the best of my current state of knowledge, the MIT group were the first to spell out in a compelling photonic band-gap theoretical framework, both conditions —necessary and sufficient—needed for such a structure to occur. In addition, they performed a convincing experiment demonstrating the effect. Finally, they published these results in a refereed journal article, which subsequently found a wide audience. Perhaps the existence of such structures in some form or another was well known to a small minority, but a large majority of the members of the optics community were simply not aware of this interesting and important result, or of the complete set of conditions needed for it to occur. The specifications of these precise theoretical conditions—together with their experimental implementation—are the primary novel scientific contributions of the recent MIT paper, which I dare say most of us in this community have received with great enthusiasm.

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Brown Dwarf Origins

In Alexander Hellemans's article "Binaries answer riddle of brown dwarf origins" (News of the Week, 13 Nov., p. 1240), I am quoted as saying that the G 196-3 binary system consisting of an M-type star and a brown dwarf is "too young...for the dwarf to have formed from an accretion disk, like a planet" and that, "[b]ecause the brown dwarf is so far away from the star, fragmentation of a molecular cloud is the most likely scenario for its formation."

I would like to clarify that what I meant was that the evidence collected by Rafael Rebolo *et al.* (Reports, 13 Nov., p. 1309) on G 196-3 and by E. L. Martin *et al.* on CFHT-PI-18 (*1*), a binary consisting of two brown dwarfs, indicates that brown dwarf binary companions (to normal stars or brown dwarfs) are more likely to form by fragmentation than in an accretion disk. In particular, the brown dwarf binary companions in CFHT-PI-18 most certainly formed by fragmentation, simply because a brown dwarf is unlikely to have an ac-