small default grant, say, $3000 to $5000 per year (but could apply for higher amounts on a competitive basis, if they wish), makes much more sense, both economically and socially, than the "winner takes all" selectivity model. The award of such a minimal grant should be based only on evidence of ongoing productivity—for example, one or two peer-reviewed papers each year. No proposal writing should be required for these default grants, apart from perhaps a one-page summary that should not require a separate peer review if copies of the applicant's peer-reviewed papers are attached. More details and an extensive bibliography can be found in reference 1.

Reference

1. A. A. Berezin, *Interdisciplinary Sci. Rev.* **26**(2), 97 (2001).

Alexander A. Berezin
(berezin@mcmaster.ca)
McMaster University
Hamilton, Ontario, Canada

I would like to offer two components that I think Howard Birnbaum underemphasizes in his accurate and useful discussion of problems that have developed with university research funding. These are my personal observations, distilled from decades of trying to play the game.

The first concerns peer review of proposals, which many of us, forgetting that peer review can be no better than the peers, are loath to disparage. In my 40-plus years of experience, the process has changed almost beyond recognition. I remember when peer reviewing was essentially free of self-interest on the reviewer's part: A proposal showed up in the mail, often submitted not in response to some "announced opportunity" stating that research funds were available, but because an individual investigator had an idea he or she wanted to pursue—and one reviewed it in that light, then sent it back.

Today, the process seems anything but individual or disinterested. The peers have a level of awareness of each other and networks of connection and organization that surpass anything imaginable in the 1960s. Potential research collaborators formally combine with a deliberate effort to add so many prestigious names to a proposal that a junior reviewer would have to be very brave to do anything but approve it. The proposers are well aware that they will be among each other's reviewers and that personalities will matter.

The peer review process is enhanced by agencies that advocate "critical mass" and "adequacy of facilities" as necessary criteria for a proposal's viability. The funding needs for some research groups are so large and so continuous that every announced opportunity is followed up with a proposal, whether or not any prior interest or expertise in the specific area was present in the group. Groups propose first and ask questions afterward, often on a very short time scale; many are still looking for new collaborators a week or two before the proposal is due.

Formal but minimal commitments, in terms of time allotted, may be spread over many proposals for a single prominent investigator. Principal investigators will often appear on different multi-institutional proposals in competition for the same funding. That type of competition could only be altered by a new and uniform set of civil-service rules and procedures that the present generation of agency managers would not know how to enforce. Rules for dealing with, regulating, and avoiding conflict of interest within government agencies have been historically rather scrupulously enforced; but application of conflict-of-interest regulations in nongovernmental applications for agency programs seems often to be essentially nonexistent or unenforceable. (And if the agencies tried to implement such regulations, they would be said to be behaving "bureaucratically.")

My other topic is the use of now indispensable graduate student labor in university research programs, usually programs supported by federal grants. There is no cheaper source of high-quality labor, and it frequently comes with a level of motivation not available at any price. Graduate students are intensely interested in the research and would like to pursue it after they finish their education. It is insufficient to tell them when they are applying to graduate degree programs that the buyer should beware and that opportunities to continue doing basic research may be in very short supply when they finish their PhDs. Such warnings only filter out the brightest American students, who are typically better attuned to the practical consequences of their educational choices and better able to choose from a wide range of possibilities—the students who should continue doing basic research in physics for the rest of their lives. The productivity of any research group is surely much greater if several graduate students are involved. The only mechanism I can imagine that would end this practice would be to give funding agencies the authority and competence to stop rewarding universities for the overproduction of PhDs in physics. It would not be an easy task, and the overall national research effort would go more slowly. But difficult problems sometimes do not have easy solutions.

David Montgomery
(david.c.montgomery@dartmouth.edu)
Dartmouth College
Hanover, New Hampshire

Birnbaum replies: I had hoped that my article would open a discussion of this important factor in US science. After that article was published, I received communications from many individuals; most agreed with the points I made but were not anxious to go public with their views. I appreciate these three writers' willingness to engage in such a discussion.

Gregory Salamo's letter focuses on the role and effect of outreach programs in the funding of science. He argues that it is the scientists' responsibility to involve all parts of our society in the understanding and excitement of science and to extend to underrepresented segments of society opportunities to engage in science and engineering. This statement, with its aspects of "motherhood and apple pie," is one I fully agree with. The issue is how this involvement is done and whether the programs are effective. Such programs as EPSCOR have existed long enough to allow a careful determination of their effectiveness in extending science opportunities to researchers in states that have not received their share of federal funding. In the absence of such a determination, the suspicion, which I would hope is not correct, arises that this is one more entitlement program. I cannot agree with Salamo that such a program can be justified on the basis that "it is, therefore, simply good strategy to engage every state in this endeavor."

Certainly the responsibility for communicating the importance and excitement of science and engineering to young students, our political structure, and other segments of society rests on all who are engaged in teaching and research. Outreach efforts require both time and funds.

Those interested in spending the time should be supported and encouraged. However, I believe that it is harmful to require such outreach as a precondition of receiving research funding (NSF has this requirement for both multi-investigator and single-investigator grants). Such a requirement results in imaginative promises that often contain more than a little hypocrisy. Some of the promised outreach efforts actually achieve their goals; those should be appreciated. More do not, and although Salamo suggests that outreach efforts are evaluated during contract renewals, my experience is that the "evaluations" are relatively pro forma.

As far as I know, no determination has been made of whether such outreach activities are cost-effective overall. And there is a cost—in expended funds (in a period when the size of grants has decreased in constant dollars); in time spent; and, most important, in the loss of support for high-quality science and engineering because, during the proposal review process, the outreach effort was judged to be inadequate. In contrast to Salamo's statement, I do believe that society benefits when research funding "supports the best to do the best."

Incidentally, NSF has a division of education and human resources, whose specific mission is to support the outreach activities being discussed and whose budget ($875 million in fiscal year 2002) is comparable to that of the division of mathematical and physical sciences ($920 million in FY 2002). Because NSF's primary mission is support of science and engineering, obvious questions arise when the dollar cost of outreach comes from the MPS budget.

Alexander Berezin has expressed a belief that the research abilities of all tenured faculty are equivalent. I cannot join him in that belief. To distribute research funds uniformly to all faculty who publish one or two papers in a refereed journal would, I believe, be extremely wasteful when research funds are already in short supply. I cannot believe that this distribution method would result in increased "serendipity, creativity, and originality in research" as Berezin expects. Similar systems are used in Japan and France, and an examination of their university research systems leads me to a strong preference for a true peer-review system.

Although I generally agree with David Montgomery about the peer-review system, I still believe that it is the best way to choose excellent research programs. The trick is to work with funding agencies to improve the system; the first step would be to undertake a frank discussion between the research community and the funding agencies. To date, this has not even started.

One issue that Montgomery briefly mentions is the "call for proposals" that increasingly forms the basis for research funding. The agencies often claim that the research community generates research topics, but in reality those topics used in the calls for proposals result either from the interests of agency personnel or from the agency's attempts to increase its funding. In either case, the topics funded are determined by groups other than the active research community. Although

continued on page 71

continued from page 15

that approach is appropriate for mission agencies, it seems less so for basic research agencies.

Howard Birnbaum
(hbirnbau@uiuc.edu)
University of Illinois
Urbana-Champaign

Readers Illuminate Issues of Solid-State Lighting

It is refreshing to find proponents of solid-state light sources (SSLs) addressing the all-important issue of cost, as Arpad Bergh, George Craford, Anil Duggal, and Roland Haitz did (Physics Today, December 2001, page 42). It is also gratifying to see the steady progression of reduction in cost per lumen shown in figure 2 of their article. The authors note that white-light SSLs must reach costs of $0.05 per lumen to be economically justified in replacing incandescent light sources for residential use.

For a number of years, I was the director of R&D for a major US lamp company (see Physics Today, February 2001, page 38), and am presently an independent consultant specializing in the science and technology of light sources. I would like to make two points. The lesser one is to ask for a better definition of "cost." There are many possible definitions of the cost of a mass-produced, mass-merchandized item. The direct cost of manufacture is the cost of materials plus the cost of labor plus overhead for the manufacturing process. The total manufacturing cost (TMC) also includes the allocated cost of the facilities and automated manufacturing equipment, including capital expenses. To get the retail cost to the consumer, one must add costs for warehousing, transportation, advertising, and distribution to retailers, and the cost of retailing itself. The retailer of incandescent lamps typically keeps $0.25–$0.30 out of every customer's dollar to cover his costs. The net result is that the retail price to the consumer for such a mass-produced and mass-merchandised item is typically 10 or more times the direct cost of manufacture. To which of these costs does figure 2 refer?

My second, and major, point is that a product presently on the market is the functional equivalent of the incandescent lamp in size, lumen output, color, and color rendering, but triple the efficacy, and it is available for $0.05 per lumen retail cost to the consumer: the compact fluorescent lamp (CFL). Its sales are minuscule. Despite elaborate charts demonstrating payback through energy savings in one year, residential customers don't buy them. The market dynamics are simple: The customer goes to the grocery store to buy supplies, with light bulbs on the list. The choice is stark: $2 for a four-pack of incandescent bulbs and steak for dinner or $30–40 for a four-pack of CFLs and beans for dinner. Why should SSLs be any different?

There is a mechanism for overcoming this obstacle, but its use is very limited. My local electric utility purchases CFLs in bulk and leases them at $0.20 per month to its retail customers. The typical customer saves $0.50 in electricity costs per bulb per month, and so achieves a net savings of $0.30 per bulb per month from day one (assuming replacement of 75-watt incandescent bulbs). Total household monthly savings then, without any up-front investment, are $0.30 times the number of bulbs replaced. The utility reduces its peak demand load by 50 watts per unit, and it only pays wholesale cost (say, $5) for the product, thereby increasing its effective capacity at a cost of $100 per kilowatt, instead of more than $1000 per kilowatt to build new generating plants. This ingenious scheme is actually limited to utilities whose peak load occurs on winter nights, which applies to fewer and fewer utilities today.

Articles elsewhere on the subject of SSLs have suggested that government funds of $50 million per year invested in supporting SSL development could greatly assist in meeting the ambitious goals the SSL community has set for itself.

If the government wants to spend money, it can achieve lighting-energy conservation goals with certainty today, not just possibly in the future; it should spend the $50 million to subsidize the lease program for CFLs, purchasing them at wholesale cost and furnishing them to all utilities to lease at nominal costs to their residential customers. The $50 million would buy 15 million CFLs, each saving 50 watts, or 300 kilowatt hours, over its five-year working life in residential service. The program could be self-supporting by means of a 27% tax on the total lease payments of $180 million generated by the 15 million lamps over their lifetime. Such a self-supporting program, continued over several years, could replace incandescent lamps in many homes with CFLs without requiring the retail customer to bear the burden of the up-front cost. A larger annual expenditure would accelerate the conversion.

Supporting the product that today does everything in replacing residential incandescent lamps that is claimed for SSL lamps in the future, and needing only a way to break through the market constraints, would be a much more effective investment for the government. Even if the SSL community achieves every one of its ambitious technical goals on time, it will still need some similar mechanism to penetrate the marketplace.

John F. Waymouth
(jfwaymouth@attbi.com)
Marblehead, Massachusetts

I applaud the authors' efforts to present a tutorial and current status of the field of solid-state lighting. However, I feel compelled to point out two omissions. The first is the attribution of credit to only Nick Holonyak and his coauthor[1] for "the first practical demonstration of LEDs in 1962." The paper by Holonyak and S. F. Bevacqua was on semiconductor lasers and has very little to do with LEDs per se. However, if we allow that paper to be a relevant reference for first LEDs, then we must include reference to three other papers[2] published at very nearly the same time as Holonyak and Bevacqua's, as also being "first" practical demonstrations of LEDs. The article by Bergh and coauthors does not distinguish visible LEDs from infrared LEDs. And to be fair about the history of visible LEDs, we should include Henry Round's publication[3] in 1907 of visible electroluminescence from SiC, the material of choice for blue LEDs before the appearance of GaN-based green and blue LEDs.

The second problem has to do with the data presented in figure 1 of the article. The data there for AlGaAs/GaAs red LEDs start in the early 1980s. In fact, data for "practical" AlGaAs LEDs started with a 1967 paper,[4] which was the first report of practical AlGaAs LEDs in the open literature. This paper also represented the first publication of a practical heterojunction.