that neither field can be justified economically. He observes that much of science is "curiosity-driven," for the "sole aim [of] discovery and enlightenment," and hence unrelated to economic or other tangible benefit to society. He may have characterized correctly the motivations for many scientists, but that is a very different thing from identifying the value of science for society—from which can derive the justification for governmental support for science. It is hardly necessary to say that history shows us that enormous utility has been provided over the ages by the results of curiosity-driven scientific pursuits. This fact sharply differentiates science from art in any attempt to justify societal economic support.

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Emmert's editorial suggesting that scientists support the NEA is right on. Unfortunately, it seems doubtful that it will get much attention. Scientists appear to rely on the proposition that the pie is only so big and someone else's slice necessarily fixes or reduces yours. In a time when science wants a bigger and bigger slice, they aren't likely to think about supporting others. This short-run view—often held by administrators, too—while unfortunate, will prevail until the demonstrably false proposition is, in fact, demonstrated to be false by courageous risk-takers.

Gwen Andrew
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Response: Thompson is only partly correct when he restates my belief that the purpose of art is to "propose new ways of envisioning the world." I also believe this is the role of science. My point is that the most important work in *both* science and art reveals new ways of understanding the world around us.

It is also scientific hubris to assert that *all* science "enriches us" and is worthy of support, while the NEA does not merit funding because some projects offend popular values. If we put all proposals for curiosity-driven research up for popular vote, a great deal of very important science would not be supported.

I agree with Baschetti that the practical consequences of scientific and artistic achievements are hugely different. I do not argue that science and art should be funded in a similar manner or in similar amounts. This has never been the case, nor should it be. My argument is simply that we need to defend funding for the arts as well as for curiosity-driven science, despite the fact that neither can be justified fully on grounds of economic return. Where Baschetti and I appear to disagree is on the importance of art. I believe that many human lives would be diminished if we lived in a world devoid of great artistic works.

Murray suggests that my argument includes the notion that "neither [science nor art] can be justified economically." On the contrary, I state clearly that the best case for science rests upon long-term financial return. My point is that we must continue to pursue curiosity-driven research even where there is no obvious economic return. To justify funding for basic research we must rely, at least in part, on the same sense of human curiosity and creativity that undergirds artistic pursuits. We do so in response to our human spirit, not just our pocketbooks.

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Fusion Alternatives

Norman Rostoker *et al.* (Article, 21 Nov., p. 1419) describe the concept of a colliding beam fusion reactor (CBFR) that has attracted significant attention in the popular press. It is clear that the media and the public recognize the importance of fusion energy; consequently, the promise of a simple and quick route to fusion is attractive. But there are some serious technical concerns associated with the CBFR concept. Two prominent ones are (i) the extreme difficulty of achieving positive power balance from even an idealized proton–boron-11 (p-11B) reaction process and (ii) the likelihood of unacceptable electron heat losses from such a small (a few centimeters) field-reversed configuration plasma, attempting to burn p-11B. The field-reversed configuration itself, however, is interesting, and excellent research in this area is being pursued at the University of Washington.

I would also like to point out that in the currently proposed deuterium-tritium Tokamak power plant designs, the Tokamak does not need to come in unit sizes of 10 gigawatts of electric power. Designs to date have been focused on unit sizes of 1 gigawatt, similar to existing power plants. Low-activation materials under development for fusion are projected to result in acceptable levels of relatively short-lived radioactive waste, and the problems of uncontrolled runaway and afterheat are not present in any fusion system. The CBFR seems to have about the same 2 megawatts per square meter of power load that Rostoker *et al.* attribute to a Tokamak. Finally, the issue of maintenance is partially in the eye of the beholder. It depends more on design and access than on linear versus toroidal geometry. An inverse cyclotron may not be simpler to maintain than a steam turbine.

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In the article by Rostoker *et al.*, the advantages of the field-reversed configuration (FRC) on the basis of fusion reaction p-11B are pointed out. This reaction is neutron-free and makes more energy than it consumes, but only by heroic energy conversion techniques and then with considerable recirculating power. The deuterium-tritium reaction makes much more energy than it consumes and at higher power densities, but it makes copious energetic neutrons. These neutrons can be intercepted before they reach the chambers walls in a flowing liquid held out against the walls by a certain amount of spinning. The liquid is a self-healing material relative to neutron damage, the structural material will last the life of the plant, and the neutrons activate ordinary stainless steel so little as to be designated a "low activation" material (*1*). One could get much more power out of a facility of the size discussed in the article, which would possibly permit a much lower cost of electricity. The FRC performance adequate for a deuterium-tritium fusion could be demonstrated soon; it is small and uses a lower magnetic-field strength than that needed for the p-11B fusion reaction.

We will all benefit greatly from work at the University of Washington and elsewhere on experimentally proving one way or the other whether the simple FRC will work as the authors describe. Its advantages over a Tokamak are enormous.

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Response: We agree that it is a challenge to achieve a positive power balance from the p-11B reaction. We explained in the "Issues and solutions" section of our article how the favorable properties of a field-reversed configuration plasma must be combined with an exploitation of the resonance in the fusion cross section and the use of an efficient energy extraction, such as the inverse cyclotron. The plasma parameters obtained thus far are preliminary, and extensive simulations and experiments are needed to optimize them.

In the same section, it is also pointed out that an excellent vacuum will exist between the plasma and the wall, and the plasma will be positively charged. Therefore, the only electron heat loss will be through bremsstrahlung, and not through exchanges with the wall, as in Tokamaks.

The minimum size of a Tokamak with ignition cannot be determined from pulsed experiments. The International Thermonuclear Experimental Reactor (ITER) experiments, if successful, will decide this. Judging from the designed size of the ITER, a 10-gigawatt reactor is a reasonable estimate. In any case, even a 1-gigawatt reactor is currently viewed as commercially and technically unattractive.

Our CBFR will have only a wall power load from bremsstrahlung, absorbed as heat. The alpha particles will not hit the wall; instead, the magnetic fields will guide them into the inverse cyclotron to extract their kinetic energy.

The absence of rotating parts, any radioactivation, and most technical infrastructure connected with steam-generated electric power cannot help but simplify, and thus reduce, costs of maintenance.

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Fusion Panel Meeting

Andrew Lawler's News & Comment article "Fusion panel scored for tipping results" (14 Nov., p. 1219) ignores the main issue.

In six meetings over 6 months, a National Research Council (NRC) committee determined that some information relevant to its charge was best obtained from senior Department of Energy (DOE) officials responsible for the Science Based Stockpile Stewardship program. That was the purpose of the 6 December meeting Lawler describes, one quite in accord with NRC procedures. Lawler's article describes the meeting as between "physicist Steve Koonin of the California Institute of Technology in Pasadena, chair of the NRC panel, and DOE managers." The full committee and its NRC staff were in attendance.