LETTERS

The Structure of Glasses

A series of thought-provoking articles appeared in the special issue "Frontiers in materials science" (31 Mar., p. 1918) dealing with glass theory. Another article relating structures to modulus, *the* yardstick of structural order (even within amorphous disorder), might have further enriched the survey.

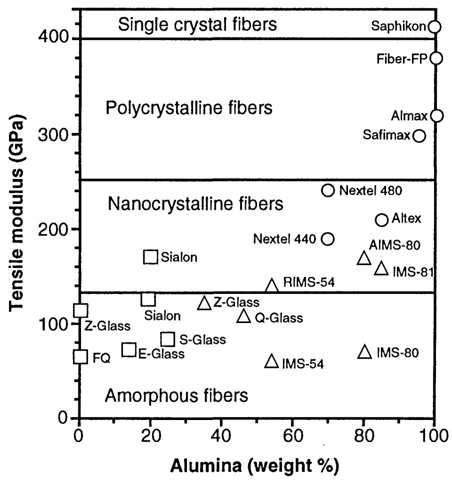

Fig. 1. Oxide fibers: Modulus versus composition and process. Amorphous and nanocrystalline fibers are glasses; polycrystalline and single crystal fibers are ceramics. (○) Sol-gel or slurry-spun fibers (all others are melt spun fibers). (□) "Strong" silicates (FQ is fused quartz, E- and S-glass are commercial fibers, and Z-glass is a zinc oxide–modified silicate). (△) "Fragile" and "inviscid" aluminates (Z-glass is a zinc oxide–modified aluminate, IMS is an inviscid melt spun fiber with a given percent alumina, RIMS is a redrawn inviscid melt spun fiber, and AIMS is a specially annealed inviscid melt spun fiber).

By way of example, one can compare (Fig. 1) the modulus of alumina-based fibers (*1*), as fibers are not only convenient specimens for structural analysis, but also potential commercial products. Thus, glasses are x-ray amorphous, yield glassy fracture, and have a structure in which the molecules are more or less randomly arranged in three dimensions. Depending on the degree of structural order, the glassy modulus ranges from 69 to 125 gigapascals (GPa), but does not correlate with composition: the structural order (modulus) of a rapidly quenched inviscid melt spun glass fiber (54% alumina) is lower than that of E-glass (15% alumina) and the same as that of fused quartz (0% alumina). As internal order (modulus) increases through compositional or process changes, or both, nanocrystalline materials with glassy fracture are obtained (125 to 250 GPa), then polycrystalline materials with brittle fracture (190 to 400 GPa), and finally single crystal materials (410 GPa). Some implications (for example, melt spun fibers with sol-gel fiber properties) may trigger new glass research (*1*) and yield new commercial bulk glasses and glass fibers (*2*).

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Economic Growth and Environmental Policy

There is much to agree with in the Policy Forum "Economic growth, carrying capacity, and the environment" by Kenneth Arrow *et al.* (28 Apr., p. 520). They argue that findings regarding downturns for certain pollutants

> imply neither that economic growth is sufficient to induce environmental improvement in general, nor that . . . the Earth's resource base is capable of supporting indefinite economic growth.

In the same vein, they conclude that economic liberalization and other policies that promote gross national product growth are not substitutes for environmental policy.

These views are not, however, expressed in the empirical papers the authors cite. These papers do not claim that the Earth's resources are limitless, and they do not assert that economic growth is a substitute for environmental policy. From the outset, researchers in this area have studied a broad mix of environmental problems, some of which appear to decline at early levels of development, some only at intermediate levels, and some not even at the highest levels. Indeed, as analysis of the authors' attributions reveals, most of the concerns they raise can be found in the very literature they are examining.

Rather than continuing to refine the rhetoric of "sustainability," we should concentrate on learning more about the economic, ecological, and political determinants of environmental change. The empirical environmental growth literature has begun to help us understand how the resolution of a given environmental problem depends on (i) "natural" economic forces, such as changes in the composition of economic activity; (ii) changes in per capita income and the associated changes in the demand for environmental quality; (iii) marginal costs of abatement; (iv) the directness with which human well-being is affected; (v) the international or intergenerational nature of the problem; (vi) the extent to which the population affected understands the stakes involved; and (vii) the nature of the political and regulatory system.

Arrow *et al.* conclude with the statement that protecting the capacity of ecological systems to sustain welfare is of as much importance to poor countries as it is to those that are rich.

In general, we can all agree with this. However, the empirical environment-development literature offers several caveats. First, poor nations are likely to have environmental problems that are different from those of rich nations. Second, their priorities regarding how to increase welfare are likely to differ from ours. Third, their ability to pay for reforms is less. Fourth, the previous three points must be viewed against the backdrop of population growth being greatest among the poorer nations and the global income distribution being highly skewed. These caveats highlight the urgency of understanding the determinants of the relationship between economic growth and environmental quality if we are to develop useful forecasts and wise policy.

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Arrow *et al.* raise some worthwhile issues, but they weaken their conclusions by resting their rhetorical lever on the anthropomorphic fulcrum of "ecosystem resilience." The view that one system state is "better" than another, that we humans, in our "bad" way, push ecosystems away from initial "good" states, and if we push too hard, things won't get "good" again, is not relevant. Ecosystems operate on a contingent, not a value, basis. Parameter states have no intrinsic "goodness" or "badness." Human technology now controls the state of the entire biosphere. We "manage" the biosphere, primarily by default. To manage effectively, we must determine what values we desire in the ecosystem (in addition to "capacity to support human life"), identify parameter states that yield those values, and manage to achieve those parameter states. Managing for a diaphanous property of "resilience" is not management at all. We would only continue our laissez-faire creep to a dispiritingly low level of environmental quality.

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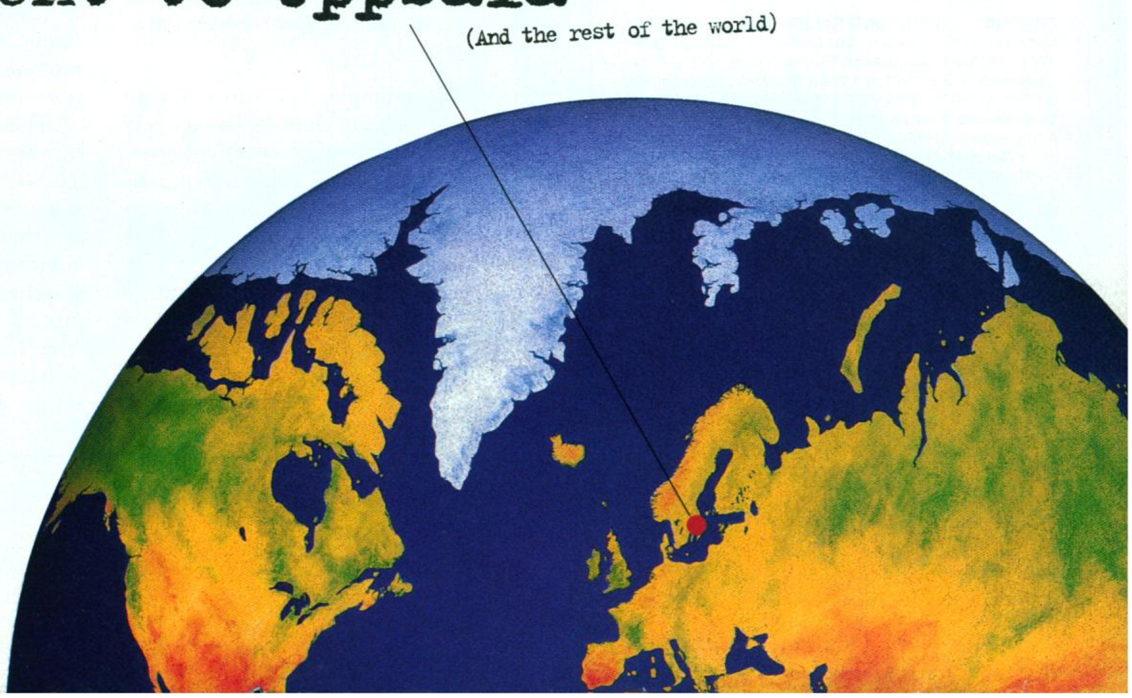
Recent empirical work (*1*, *2*) and substantive interpretations, such as that of Arrow *et al.*, are leading to an emergent, if sketchy, picture of the relationship between national prosperity and environmental quality. Arrow *et al.* provide a useful critique of the widely accepted conventional assumption that the relationship between per capita income and environmental quality is shaped like an "inverted U"—where early economic growth degrades environmental quality but later growth improves it. This caution is supported by empirical results (*2*) showing that, while the inverted U shape is sometimes observed, in many cases other patterns better describe the income-environment relationship.

Population is properly included as a con-



trol or normalizing variable in these analyses. Virtually overlooked, however, is the possibility that population itself may be a driving force in environmental quality and may behave in more complex ways than is commonly assumed. Indeed, the early results from our research program (*3*) assessing the driving forces of carbon dioxide emissions with the IPAT model (*4*) indicate that population is a significant predictor of national carbon dioxide loads across the entire spectrum of national incomes and suggest that the effects of population may be disproportionately large for the largest nations.

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Pharmaceutical Value Estimates

In his Policy Forum "The world's forests: Need for a policy appraisal" (12 May, p. 823), Norman Myers cites me as the source of estimates of the commercial value of pharmaceuticals from tropical forest plants of $25 billion per year and of the economic value of these pharmaceuticals of at least twice as large. While I do not want to detract from the thrust of Myers's Policy Forum, I would like to state precisely what estimates I made.

The first estimate to which Myers refers characterizes the retail value of plant-based pharmaceuticals in the United States. For 1990, this estimate is $15.5 billion (*1*). The pharmaceuticals included in this estimate are not limited to those derived from tropical forest species; the estimate only covers the market in the United States and it does not include over-the-counter products. The economic value estimate (which includes market value as well as intangible values, such as the value of lives saved or suffering alleviated) describes the economic value of plant-based anti-cancer pharmaceuticals in the United States, and it is about $250 billion (1983 dollars) annually (*2*). As in the retail value estimate, the pharmaceuticals are not limited to those from tropical forests, and the estimate only covers the market in the United States. The derivation and limitations of these estimates have been thoroughly described (*1, 3, 4*).

I would also call the readers' attention to the correct citation (*1*) for the work referenced by Myers.

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