bailiwicks and studiously ignored—even deprecated—the biologists who have attempted to cooperate and further the cause.

Top-heavy with amateur naturalists and professional altruists, environmental organizations are apt to strongly resist input from biologists who tell them things they do not want to hear. For example, hard facts about demography—plant, animal, or human—are unpalatable compared to soft soap on organic gardening or returnable bottles.

It is exceedingly frustrating to be the sole, "token" biologist employed by a major conservation agency and bounce repeatedly off a solid wall of bureaucratic ignorance. When the ultimate decision-makers sport baccalaureates in business administration, economics, or "environmental affairs," perceptive, responsible positions on biological issues are most unlikely.

What we need to do is "biologize" the whole environmental movement. I see signs for hope in the young, aware professionals moving up in the ranks of biologists. But I fear they may be too few and reach positions of influence too late.

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Fusion: Neutral Beam Technology

We strongly disagree with the statement by William D. Metz (Letters, 27 Oct. 1978, p. 370) that "it is generally acknowledged that the neutral beam technology used at Princeton (based on positive ions) cannot be extrapolated to a reactor-level plasma because the already modest efficiency plummets when the beam energy is raised." In fact, we believe it is likely that very high energy beams will not be needed for tokamak reactors. Early assessments (*1*) of neutral beam energy requirements indeed led to Metz's conclusion. However, these were typically made for circular, cross-section plasmas with neutral beams injected tangent to the inside edge of the plasma and with some combination of large plasma size, high density, or both. Conservative assumptions were also made about the required depth of penetration for the neutral beams. The resulting rules of thumb for injection requirements are not borne out in current conceptual designs for tokamak plasmas heated to ignition.

Because of increased understanding of tokamak plasmas, recent reassessments of beam energy requirements have led to a relaxation of some of the conservative assumptions. Smaller, elongated plasmas with nearly perpendicular injection will provide for a large decrease in beam energy requirements. These energy requirements are further reduced by low plasma density ($\bar{n}$) during the injection heating phase ($\bar{n} < 10^{14}$ ions per cubic centimeter), outward shift of the magnetic axis as the plasma pressure increases, heating of the core of the plasma by alpha particles produced in fusion reactions, and the possibility of expanding the plasma radius during the approach to ignition.

These considerations have been incorporated into new assessments (*2*) of the required neutral beam energies for a noncircular tokamak reactor plasma with a minor radius of 1.25 meters. Beam energies in the range of 100 to 150 kiloelectron volts (keV) (deuterium) are calculated to provide adequate penetration for heating to ignition. Lowering the beam energy requires increasing power input to the plasma, but the higher neutralization efficiency of lower energy positive ion beams leads to roughly constant power supply requirements over the range of energies considered (100 to 150 keV deuterium). Direct conversion of the unneutralized positive ion beams has already been demonstrated (*3*) and, when perfected, will make neutral beams based on positive ion sources an efficient heating mechanism.

If the presently estimated sizes for conceptual reactor plasmas prove to be correct, positive ion deuterium beams below 200 keV can be efficiently used to heat tokamaks to ignition, at least through the first demonstration reactor. The Princeton Large Torus results have certainly helped increase our confidence both in neutral beam heating and in scaling to reactor plasmas.

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4. Oak Ridge National Laboratory is operated by Union Carbide Corporation under contract W-7405-eng-26 with the Department of Energy.