letters

our national obsession for growth. His model would allow us to continue to escalate our rates of consumption of coal for a period t_i and would thrust on our children the onerous task of reversing this trend. This brings to mind David Brower's observation that promoting continued growth in the rates of consumption of our natural resources is simply a sophisticated way of stealing from our children. It is my hope that we could start moving in the direction of the program that I outlined, which would make our coal last forever.

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2/23/77

Plea for help

After ten years of study in the United States, I have returned to my home, Guatemala, with the purpose of helping to establish a measure of scientific competence and independence in our country. Now that I am back I feel compelled to write a plea for help from our more affluent colleagues abroad.

Scientists in developing countries are plagued by a lack of resource, not only in laboratory instrumentation and supplies, but also for the purchase of books and journals. Our institution, the only one in the country with programs in pure sciences, was set back financially by damages caused in last year's earthquake, and as a result our library has remained rather poor. Anyone who wishes to help with a donation of books and/or scientific journals that may be lying idle is encouraged to contact me.

Thank you.

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Hierarchy of sciences

The letter of James Edmonds (March, page 88) raises two questions, one serious, one silly. The first question—what is fundamental in science—is one for which each of us has his own idea.

For the sake of argument, however, I will abstract from Webster and my own ideas to suggest that a fundamental study in science is that irreducible set of definitions, postulates, ideas and rules for connecting the foregoing with observation and from which understanding of less fundamental studies may be derived. Thus for two disciplines, we may sometimes have the situation where one is fundamental and one is derived, each relative to the other.

If one leaves off observation, one might also apply the definition to mathematics and find that there are fundamental and derived mathematical studies. However, here one immediately sees a difficulty. Consider two geometries based on mutually exclusive postulates. Neither can be said to be more fundamental than the other.

The physicist has, over the last 100 years, obtained the impression that there is a hierarchy of studies, the lower or more "fundamental" generally containing the upper or "derived." Thus one expects to derive the rules of chemistry, how atoms behave in molecules, from the more fundamental study of quantum mechanics of nuclei and electrons, and, similarly, one expects to derive nuclear physics from the more fundamental study of the physics of particles, once its rules become clear. Even in this conventional picture, however, one must make allowance for the possibility that new postulates or definitions must be added to obtain the derived from the fundamental. For example (leaving aside quantum mechanics) one must add the ideas of randomness and averages to the postulates of classical mechanics to obtain statistical mechanics. Hence there may be subjects that fit into the hierarchy, but which nevertheless require new postulates and definitions. This is not dissimilar from Gödel's demonstration that in any system of mathematics one may define hypotheses that are testable for truth or falsehood, only by adding to the postulates of the system. Until one has shown by solution (or at least rigorous demonstration of the possibility of solution) of the problems which arise "naturally" within the context of a complex system, using the postulates of a simpler system, one can't be sure that additional postulates will not be required to encompass the more complex system.

As another example, it seems to me that there are fundamental and open questions in biophysics. Certainly the laws of physics are obeyed by the constituents of biological systems. Still, no one has shown that any predictive theory of any important biological properties can be derived from the physics of constituent atoms and molecules without the addition of new definitions and ideas (that is, the ideas of language must certainly be used in understanding the molecular basis of life, and these are not derivable from the physics of atoms and molecules).

Suppose, however, that the hierarchy exists without the exceptions and orthogonal directions that may, nonetheless, exist. There is no indication that it ever ends. That is, if a subquantum physics is finally ironed out, no one can ever disprove the existence of a subphysics beyond that, which may eventually be discovered by accelerating particles to still higher energies. The situation is at least as indeterminate on the cosmic scale, and with respect to connecting cosmology to microscopic physics. Eventually our re-

continued on page 82