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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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-

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sources must run out; but we can hope at best for consistency, not for a proof that we have gotten to the bottom of things.

The world may, as some think, be built from a lowest level that is a finite number of stories below our present understanding. If the world is, however, like a building with infinitely many stories (and only by an act of faith can one say that it is not), then it would be stretching a point to say that the minus third floor is fundamental while the minus second is not.

The second question raised is more easily dealt with. That is, should we call material scientists, plasma physicists, astrophysicists, biophysicists, solid-state physicists, chemical physicists and (according to the above) nuclear physicists by the name Edmonds suggested (you should excuse the pronunciation), "physists." I suggest we simply stay with material scientists, plasma physicists, and so on or more simply, applied physicist or physicist depending on whom the scientist is trying to impress.

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THE AUTHOR COMMENTS: Burt Bronk has brought up several important issues concerning the nature of scientific reality and human perception, in the division between physics and "applied" physics (materials science). Both "applied physicist" and "materials scientist" can be misleading labels, because the study of biophysistry or semiconductor physistry need not be "applied" at all, in the technological sense, and certainly crystals or liquids are no more material than protons or electrons. An agreed-upon new term is needed here, even if no philosophical distinction is intended. We can simply define that body of basic enquiry where quantum electrodynamics suffices (in principle), as the field of physistry.

The "in principle" remark above relates to the main substance of Bronk's comments. I agree that it is a matter of faith that the whole is not more than its parts in nature. Most physical scientists, I think, subjectively subscribe to this faith, and will do so until experimental evidence (meeting standard criteria of scientific reliability) is produced to the contrary. Even the simple helium atom cannot be calculated without elaborate effort and resort to numerical methods. It is, therefore, unfair to require prediction that DNA molecules should be right-handed instead of left from solving the Hamiltonian for such a molecule. The burden of proof rests with the other side, however, to show why it should not suffice, in principle. We must always keep an open mind to this possibility.

The "boxes within boxes" question of approximate paradigms (treated in some depth in my forthcoming book, *Philosophical Physics*) is quite separate and very profound. First, may I comment as Richard Feynman often did in his lectures, "How can you prove anything?" Physics is at best a computational/conceptual scheme that predicts (in principle) all measurements that humans can make. If and when such a state is ever reached, then physics is finished until someone finds *one* measurement that "contradicts" the theory. If none is found, then there is no more physics to be done, there is only physistry. Whether "deeper layers of truth" exist, unseen, is unanswerable and a matter of pure faith. Heisenberg has said,

> "It is pointed out that with the building of ever larger accelerators we are pushing forward to ever higher energies in the colliding elementary particles, and that in the process a new region, still unknown, may be revealed. But this view rests on a supposition without warrant in either experience or theory, namely that with a further increase in the energies, qualitatively new phenomena are bound to appear. In cosmic radiation, where the energies of the colliding particles can be up to a thousand times greater than in the largest accelerators yet built, no such qualitatively new phenomena have been found."

Successfully predicting the many properties of the subatomic quanta may well be the last layer humans can uncover and "understand." It may be solved in 10 years or in 10 000 years, we just don't know; the *basic conceptual tools* are unknown, contrary to those of the world of physistry—this is the big difference.

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More on standard references

Paul Meijer has raised a significant point in his letter in the May issue (page 100) concerning the need for international standardization of references, and one with which the Publication Board of the AIP has grappled from time to time in the past.

It turns out that there is, in fact, a standard dealing with this matter, although it has only recently been adopted and is only now in process of being published. The American National Standards Institute (of which the AIP is a member) is publishing Standard Z39.29, American National Standard for Bibliographic References. It is not truly an international standard, as Meijer urges, but it was developed with internationally supported proposals in mind.

Unfortunately, this standard does not at all address one of the problems raised by Meijer, the ordering of references (and thus the mode of citation). It deals only