Phosphate!

. . .Stewart, listen:

Where is O'Neill going to get his phosphates? He and Drexler et. al. love to talk about iron and aluminum and hydrogen and all those lovely spacey hardwarey things but what about Leibig's Law of the Minimum — "A population is limited by whatever requisite is in shortest supply." Humans need phosphorus in the form of phosphates in their food. I haven't heard about any phosphorus on the moon, asteroids, L4 & 5, or even Jupiter. (Maybe there is; maybe nobody's talking about it.) So phosphates (among other things) will have to come from Earth. And we're in phosphate trouble. Best estimates put us out of phosphates between 2010 and 2030. (See Laing in **Not Man Apart**.). . .

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Cycles & pollution

. . . A perusal of the September 1970 issue of **Scientific American** will clearly outline the major problems to be overcome in establishing a *de novo* ecology. The following cycles will have to be "engineered" into the system: Weather (energy and water), Oxygen, Carbon, Nitrogen, Sulphur, and Minerals. This should really be self evident. In terms of Island One or Model III these cycles need to be considered in two contexts: (A) Controlled Agriculture and Food Supplies and (B) The Living Zone Biosphere. Controlling the 6 cycles in the Agricultural modules should be relatively easy, using modifications of the current hydroponics and greenhouse technologies. The establishment of a self sustaining Living Zone, however, poses much more serious problems, especially for Island One which gains most of its mass from lunar sources. The weather cycles will largely be controlled by the illumination and heating cycles engendered by the mirror systems, together with the kinetic forces generated by rotation. If one heats one side in a colony with threefold symmetry then there will be an evaporation-condensation cycle operating across the diameter of the colony. If one has alternating periods of light and dark over all surfaces simultaneously, then there will be severe fluctuations in the evaporation-cooling cycles and thunderstorms will probably result. The former system would probably give rise to heavy dews rather than rains. These patterns can probably be controlled by engineering.

The establishment of the O, C, N, S and of course, H (hydrogen) cycles largely depends on the establishment of proper soil conditions together with the requisite macro and micro flora (everything from worms to bacteriophage and back again). It seems to me that this will be a major problem, i.e., the conversion of lunar dust, which is predominantly volcanic rather than chondritic, into soil suitable for rapidly establishing a self-sustaining biosphere. The H, O, and C cycles are relatively easy in this respect, but the N and S cycles are more difficult. In this context Lynn Margulis' comment on the low pressure pure oxygen atmosphere ranks as one of the understatements of the year. All of these cycles are dependent on biotic components where enzymes and regulatory systems have evolved, in, and are best suited to, the chemical potentials and partial pressures of the environment on earth at the present time. The nitrogen cycle is not well understood in terms of quantification or systems analysis and neither is the sulphur cycle. We can talk glibly about nitrifiers and denitrifiers, but despite all of our molecular expertise, I suspect that our greenhouse man knows as much about building a self-contained ecosystem as do our ecologists.

Lastly, the mineral cycles contain sinks which are controlled by geological rather than biological processes. The main worry is the displacement of minerals and organic components, especially nitrogen, via leaching. Some mechanism must be made available for salvaging and redistributing these components from the rivers and lakes of the colony without disrupting large parts of the ecosystem. The facility with which this can be done will depend largely upon the kind of ecosystem established. The problems would be vastly different in a temperate colony as compared to a rain forest ecology. One of the principle differences would be in the rates of recycling and in the organic mass associated with detritus recycling.

One other thing that occurs to me also concerns cycling of mineral and organic components, the problems of epidemiology and chronic poisoning. Public health officials have long been aware of the potential problems encountered in sewage processing due to the potential recycling of spores and viruses which are resistant to 'normal' treatments. Agricultural scientists are currently very concerned about the possible concentration of heavy metals in agricultural produce when sewage sludges are recycled in the guise of fertilisers. I don't think I need to stress the possible deleterious effects that might occur from the accumulation of organic residues (not necessarily pesticides) such as nylon monomers, PVC, styrene, etc. in the top consumers (man) in this closed food chain. Even with industry outside the colony it will still be difficult to exclude casual contamination due to the usage of final products inside the main chamber.

I hope this doesn't sound too pessimistic because I think that many of these problems can be overcome by creative ingenuity. Also the expertise gained from building a biosphere from scratch, together with a compatible homosphere, will yield enormous benefits in knowledge for the vast majority who will remain on spaceship earth.

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Biology first

. . .We have to deal with the colony as a biological system, a wonderfully complex problem that O'Neill's groups have yet to give more than lip service to. We understand that as physicists they're not really capable of — or necessarily interested in — dealing with it, but the current strategy of ignoring that aspect and going on with the design until some biologists come along and take care of the problem is ridiculously naive. For one thing, it's the best way not to attract biologists to work with you. In our experience with the MIT group, almost no time was given to considering the biosystem since it wasn't a common interest and few people had any biological training. They had no faith in our necessarily inadequate descriptions of the complexities involved, and boundless faith in biologists' abilities to modify life forms to suit their needs.

Far from being tailored — or kluged — to fit the physical design of the colony, the ecosystem it will contain must to a large degree dictate that design. For instance, plants may grow in a nitrogen-free atmosphere because they get their nitrogen in a different form from bacteria in the soil. But where do you suppose the bacteria get it from? And as soon as you decide to dispense with the bacteria and fertilize directly with chemicals instead you've upset your minimum-energy equilibrium, and since you don't know what other functions plants (or something else in the food web) need those bacteria for, you're treading on shaky ground. This is tragic, for both the biologists who could have, in the design and eventual realization of space colonies, the perfect incentive and paradigm for exploring the Gaia hypothesis, and for the colony designers who, without an understanding of that hypothesis and its implications, will end up with an ugly and costly failure. . . .

Space colonization isn't something to rush into, and then be locked into, as a means to profit. Developed with care, as an end in itself, the space colony can be a most fertile inspiration, forcing/leading us to learn the meanings in the structure of communities, the balance of biological sufficiency, and the qualities of a sane technology, lest we export the amorphous, imbalanced insanities we live with now.

Consider that the building of worlds is the work of gods. Evolution is metamorphosis; when we leave Earth in a world we have created we will be literally and metaphorically leaving the cradle. The question is whether we break out of a ruin like a virus exploding from a shattered cell, or leave Earth as a child leaves a playpen, no longer needed but ready for the next sibling. The virus is a degenerate fragment that just replicates on; the child grows towards limits we haven't yet found.

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