Letters

Artificial Biosphere

It is unfortunate that Dyson's suggestion [*Science* **131**, 1667 (1960)] as to how intelligent beings might survive after reaching "the limits set by Malthusian principles" does not do justice to the intelligence of these beings by explaining how they would overcome some of the obstacles which, at first sight, would seem to militate against their curious way of life.

Dyson's report describes a uniformly thick shell of fluid with a thickness of a meter or two and a radius twice the earth's distance from the sun. The shell is said to revolve about the central star, which implies that the material revolves as a whole. Presumably the material of the shell must be enclosed on both surfaces by transparent plastic sheaths of similar constructions, for self-gravitation cannot be expected to make the material cohere. However it is not conceivable that it would be possible to quarry from the material of a planet like Jupiter sufficient structural steel to keep the shell rigid against the shear forces and those that would tend to move material towards the equatorial plane.

Therefore, it must be assumed that radiation pressure must play a part in supporting the shell, so that its form will be that of an oblate spheroid rather than a sphere. For example, material at the poles of revolution of the shell would be supported entirely by radiation pressure, so that the polar radius of the shell would necessarily be less than the equatorial radius. However, a cursory calculation will show that this would be possible only at a distance from the central star comparable to but less than the radius of the sun.

Beings of lesser intelligence, not having discovered the appropriate laws of physics, might therefore seek some other distribution of their dismantled Jupiter that would have more intrinsic stability—for example, a torus lying in a plane perpendicular to the axis of its own rotation. The mass of Jupiter distributed in this way would yield a torus whose cross-sectional area was comparable with that of the moon, but unfortunately the flux of stellar radiation would be reduced by a factor of 10^9.

With conventional laws of physics, however, as Laplace was the first to show, even this arrangement would not be stable, and it is to be expected that the material of the torus would coalesce into one or more planetary objects. This suggests that, in the present state of intelligence, the dispersal of Jupiter into a thin shell about the sun would

not be an effective means of escaping the consequences of continued population growth but that it might be an experiment with an important bearing on various theories of the origin of the solar system. It would, for example, be interesting to see whether the outcome of the experiment was the recreation of Jupiter or the creation of a number of asteroids.

Another point is that a search for infrared stars would be valuable even in conventional science for the light it might throw on the evolution of stars which are very young or very small as compared with the sun.

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Freeman Dyson's report suggesting that intelligent life elsewhere in the universe may be detected by looking for sources of infrared radiation was delightful. However, as an old science-fiction hand, I feel obliged to sound a cautionary note to the scientists. Or am I merely too dense to recognize a satire?

The basis of Dyson's argument is that an industrial culture may eventually occupy an artificial biosphere completely surrounding its sun, thus maximizing the territory and energy available for population expansion "to the limits set by Malthusian principles." The mass of Jupiter could be converted into an inhabited "spherical shell revolving around the sun at twice the Earth's distance from it," utilizing incident solar radiation which would be reradiated into space in the 10-micron band.

Offhand, I should think rotational and gravitational stresses alone would rule out such a structure of such dimensions. But since it is admittedly dangerous to assert that anything is impossible, I shall confine myself to questions of economics. Even Dyson intimates that the project would take several thousand years to complete; he calculates the energy required as equal to the sun's total output for eight centuries, and one does have to eat meanwhile. And meanwhile, too, the population growth necessitating this project will presumably continue. As Hauser remarks in the same issue [*Science* **131**, 1642 (1960)], at our present-day rate of increase we would reach "a population of one person per square foot of the land surface of the earth in less than 800 years." Thus, the economic surplus needed for the biosphere project would be consumed long before the latter got well started.

If we assume a ratio of population increase to industrial expansion low enough so that this contretemps does not occur, we must ask ourselves how

any intelligent species could be induced patiently to continue this enormous task, millennium after millennium. True, our human history contains epochs of grandiose and useless construction, such as the pyramid building of Egypt, but they never lasted very long. Any revolutionist who promised relief from the crushing burden of the biosphere project would be well received! He could doubtless get support for some or other population-control program; those who demurred would be martyred by exasperated taxpayers, or the equivalent thereof.

Of course, the entire species *might*, by advanced psychological techniques, be conditioned into such an antlike state that its government could never be overthrown, or break down from internal stresses, or evolve into something new. But given subjects as meek as this, and no reason to breed vast armies (for only a well-established world government could seriously entertain these ideas in the first place), the masters could regulate birth and death by fiat. Thus, the population would be stabilized at some rational figure and projects such as Dyson's would never be indicated.

In short, uncontrolled population growth will make the construction of artificial biospheres impossible, and control will make them unnecessary. So astronomical discovery of infrared sources won't prove anything about the inhabitants of other planets.

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The suggestion by Freeman J. Dyson for investigating solar far-infrared radiation as one way to detect extraterrestrial intelligence sounds quite practical and sensible.

This leads me to suspect that if Dyson's assumption is correct—that intelligent beings exist of a far higher order of technological achievement than our own—it would be well-nigh impossible for such beings *not* to have detected us.

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In reply to Maddox, Anderson, and Sloane, I would like only to add the following points, which were omitted from my earlier communication.

1) A solid shell or ring surrounding a star is mechanically impossible. The form of "biosphere" which I envisaged consists of a loose collection or swarm of objects traveling on independent orbits around the star. The size and shape of the individual objects would be chosen to suit the convenience of the inhabitants. I did not indulge in speculations concerning the constructional details of the biosphere, since the ex-

pected emission of infrared radiation is independent of such details.

2) It is a question of taste whether one believes that a stabilization of population and industry is more likely to occur close to the Malthusian limit or far below that limit. My personal belief is that only a rigid "police state" would be likely to stablize itself far below the Malthusian limit. I consider that an open society would be likely to expand by a proliferation of "city-states" each pursuing an independent orbit in space. Such an expansion need not be planned or dictatorially imposed; unless it were forcibly stopped it would result in the gradual emergence of an artificial biosphere of the kind I have suggested. This argument is admittedly anthropomorphic, and I present it in full knowledge that the concepts of "police state" and "open society" are probably meaningless outside our own species.

3) The discovery of an intense point source of infrared radiation would not by itself imply that extraterrestrial intelligence had been found. On the contrary, one of the strongest reasons for conducting a search for such sources is that many new types of natural astronomical objects might be discovered.

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Hazards and Insecticides

Philip R. White states [*Science* **131**, 614 (26 Feb. 1960)] that "the problem" is much wider than "poisoned cranberries," chickens, and so on; that "the problem" is a "premature or inadequately prepared commercialization of scientific finding." White fortifies his opinion with a few cases, stating that these must be only a few of hundreds. White has presented only one side of the coin. That certain cases do represent a very dangerous trend is true, but the reverse side of the coin may be equally dangerous.

Pray let me, like White, cite a few examples. In the last few years this laboratory has tested two chemicals that came to us from Europe, highly recommended. In both cases we found the materials ineffective although not in any way dangerous. One of these was already on the market in Europe but was withdrawn because our work proved it ineffective. This case parallels the case of the French weed killers cited by White.

In the 1930's *Anopheles gambiae* was rampant in the valley of Rio Grande do Norte in northeastern Brazil. Many scientists (altogether too many) stated dogmatically that it was impossible to eradicate these mosquitoes, that the misery, sickness, social disorders, and death visited upon Rio Grande do Norte were inevitable for the Western Hemisphere from Buenos Aires to Galveston. Fortunately a small group of scientists supported by the Rockefeller Foundation and the Brazilian Government staked their honor and reputations, but not their lives, in a scientific Thermopylae. They used the tools available—namely, pyrethrum of evanescent efficacy and paris green of extremely high toxicity. In 2 years morbidity cases among the field workers numbered 595. Compare this with statistics for the village of Caicó (some 600 inhabitants), where there were 64 fatalities in the month of May 1959 as a direct result of invasion by *Anopheles gambiae*. *Anopheles gambiae* was eradicated in the Western Hemisphere, although the only weapons available were ineffective or hazardous by present scientific standards. The incident is forgotten, although it has been fully published and the report is readily available for anyone's perusal [F. L. Soper and B. Wilson, *Anopheles gambiae in Brazil* (Rockefeller Foundation)].

Today in the northeastern United States the dairy industry is confronted