February 22, 1961

Dr. Carl Sagan
University of California
Berkeley Astronomical Department
Berkeley 4, California

Dear Dr. Sagan:

Your letter arrived just after I had sent a set of revisions to Dr. DuShane. However, I was sufficiently swayed by your arguments to make still another revision at the risk of incurring the wrath of the editor. You will find it indicated in the enclosed letter.

I, too, had considered a combination of a spherical and a planar distribution, as mentioned in my footnote 3. Since I used a somewhat greater value for the thickness of the galaxy, I obtained an even smaller difference between the two models.

I agree that w would be smaller <u>if</u> the stars in the solar neighborhood had been closer to each other at some time in the past and <u>if</u> life had evolved very rapidly at that time. However, the stars could not have been ten times closer to the Sun than they are now, for otherwise the Sun would not have retained its cometary belt. Moreover, if I am not mistaken, these clusters are usually quite small, on the order of 10^3 stars. Therefore, such a cluster cannot contribute much material, even if it is situated close to the Sun. For example, if the 38 grams of cosmobiota all came from Alpha Centauri, then w for that star would have to be 4.5×10^{21} grams. Even if you placed 1000 stars at the distance of Alpha Centauri, w would still have to be 4.5×10^{18} grams.

I also doubt whether extra-galactic biota could ever have made a significant contribution to the lunar population. True, the galaxies may have been much closer to each other some time in the past, but the Moon is only 4.5 aeons old, and if the present value of the Hubble constant is at all correct, then most of the expansion must have taken place before the birth of the Moon.

Your estimate of the ejection of soil by meteorite impact is probably over-optimistic on several counts. First, only crater-forming meteorites of at least several hundred tons weight are likely to propel any material to the required high velocities. On the other hand, the microorganisms will reside only in the top soil, and since the depth of the crater is approximately equal to five times a meteorite diameter, the amount of top soil ejected by larger meteorites will go up only as the 2/3 power of the mass.

Finally, the argument in my paper concerning lunar craters indicates that the velocity distribution peaks below 2 km/sec with only a relatively small fraction at the circumlunar velocity. The small mass deficit of lunar craters indicates that the integral of the velocity distribution between 0 and 1.7 km/sec must be about 80 or 90%. If you use these data to construct a Maxwell-Boltzmann or any other reasonable kind of distribution, you will find that only a very minute fraction, far less than 1% of the material, can be propelled to the required high velocities.

I am sorry, of course, that I neglected to consider the fascinating possibilities pointed out in your paper. I hope the proposed revision meets your objections. However, I

feel that a decision concerning sterilization of lunar vehicles should be made after careful appraisal of all pros and cons. So far, only the pros have been discussed in the literature, and I doubt whether any harm can result from a single con.

I, too, hope that we shall have further opportunities to discuss this and other related problems. I shall be in Washington at the Theoretical Division of the Goddard Space Flight Center during March and April. Any hope of seeing you there?

With best regards,

Yours very sincerely,

Edward Anders

Edward Anders

EA:mb

cc: Dr. Lederberg