letters Journal of proteome research

Living Nanovesicles—Chemical and Physical Survival Strategies of Primordial Biosystems

Andrei P. Sommer,*,† David S. McKay,‡ Neva Ciftcioglu,§ Uri Oron,|| Adam R. Mester,⊥ and E. Olavi Kajander#

Central Institute of Biomedical Engineering, University of Ulm, 89081 Ulm, Germany, National Aeronautics and Space Administration/Johnson Space Center, Houston, Texas 77058, Universities Space Research Association, National Aeronautics and Space Administration/Johnson Space Center, Houston, Texas 77058, Department of Zoology, Faculty of Life Sciences, Tel-Aviv University, Ramat-Aviv, 69978 Tel-Aviv, Israel, Department of Radiology and Oncotherapy, Semmelweis University of Medicine, 1082 Budapest, Hungary, and Department of Biochemistry, University of Kuopio, 70211 Kuopio, Finland

Received January 23, 2003; Revised Manuscript Received February 24, 2003

Life on Earth and Mars could have started with self-assembled nanovesicles similar to the present nanobacteria (NB). To resist extreme environmental stress situations and periods of nutritional deprivation, nanovesicles would have had a chemical composition protected by a closed mineralized compartment, facilitating their development in a primordial soup, or other early wet environment. Their survivability would have been enhanced if they had mechanisms for metabolic communication, and an ability to collect primordially available energy forms. Here, we establish an irreducible model system for life formation starting with NB.

Keywords: nanobacteria • nannobacteria • nanovesicles • extremophiles • origin of life models

[illegible] NB,[1] [illegible] NB [illegible][2] [illegible] NB [illegible][3] [illegible] NB [illegible][4] [illegible][5] [illegible] NB-[illegible]

(1) A [illegible]

(2) A [illegible][6] [illegible] 0.1 nHCL [illegible] 20 °C [illegible] NB, [illegible]

(3) [illegible] NB [illegible] 15 [illegible] 30 [illegible]

(4) A [illegible]

(5) A [illegible]

---

* To [illegible] E-[illegible] @[illegible]

† [illegible]

‡ [illegible]

§ [illegible]

|| [illegible]

⊥ [illegible]

\# [illegible]

10.1021/pr034005h CCC: $25.00 © 2003 American Chemical Society

Published on Web 03/21/2003

(6) A [illegible] C [illegible] A [illegible] [7]

(7) A [illegible] T [illegible] [4] L [illegible]

A [illegible] ALH 84001,[8,9] [illegible]). T [illegible] M [illegible] NB [illegible] M [illegible] NB, [illegible] 3.9 Gy [10] [illegible] E [illegible] T [illegible] NB, [illegible] 80 to 300 nm [illegible] RNA [illegible] DNA [illegible] NB. NB [illegible] [11] H [illegible] [12] NB's [illegible] NB. [13] T [illegible] NB's [illegible] R [illegible] D [illegible] C [illegible] R [illegible] B [illegible] [14]

In [illegible] A [illegible] 1.6. Th [illegible] [15] [illegible] (NOA), [16,17] [illegible] NB. T [illegible] E [illegible] NB [illegible] a [illegible] a [illegible] [4] T [illegible] (∼1000 W/m^{2}). T [illegible]

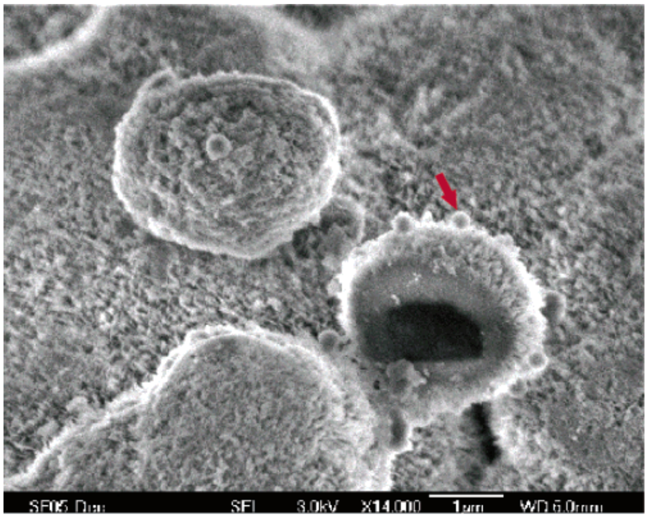

Figure 1. Three giant nanobacteria formed in serum-free media (DMEM) within one month culture period, SEM-image, bar 1 μm. The equiradial spherical satellites (Ø ≈ 200 nm) attached to the apatite igloo (→ small arrow) are presumably nanobacteria liberated from one mother cavity in which they matured together.

4 × 10^{4} Jm^{-2}. E [illegible] [18] [illegible] [2] [illegible] [19] [illegible] [20] [illegible] — [illegible] E [illegible] — [illegible] NB [illegible] NB, [illegible] NB [illegible]

L [illegible] 1000 W/m^{2} [illegible] [21] [illegible] — [illegible] D [illegible] 1000 W/m^{2} [illegible] (Fig. 1), [illegible] (Fig. 2). R [illegible] NB, [illegible] [24]

By [illegible] RNA, NB [illegible] T [illegible] [22,23] I [illegible] NB [illegible] [24,25]

I [illegible] NB [illegible] [24] I [illegible] NB [illegible]

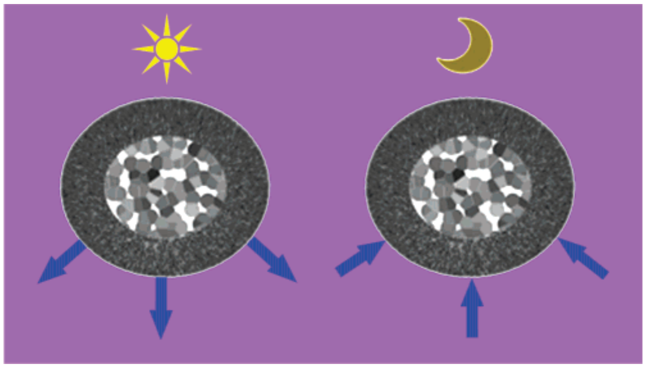

Figure 2. Artist's view of the light effect on nanoscale biosystems coated with apatite: Irradiation and differential heating with light intensities of the order of the solar constant causes fluid outflow via the porous apatite shell (left). Darkness reverses the processes in the cavity, causing inflow of fluids and nutrients. Light-induced diurnal temperature variations may have a "natural thermocycler" effect on nucleic acids.

[illegible] RNA [illegible] NB [illegible] RNA, [illegible] RNA [illegible] RNA [illegible] NB [illegible][24] [illegible]

[illegible] NB [illegible] NB.[5,26] [illegible][27,28] NB [illegible]

[illegible]

References

(1) [illegible] J. T.; [illegible] R. *FEMS Microbiol. Rev.* **2001**, *25*, 573.
(2) [illegible] G.; [illegible] T. A.; [illegible] L.; [illegible] J. G.; [illegible] [illegible] O. *J. Cell Sci.* **2002**, *115*, 1461.
(3) [illegible] [illegible] T.; [illegible] A.; [illegible] D.; [illegible] R.; [illegible] G.; [illegible] [illegible] L.; [illegible] T.; [illegible] C.; [illegible] S. B. *Circulation* **2001**, *103*, 296.
(4) [illegible] A. P.; [illegible] H. I.; [illegible] E. O. *J. Clin. Laser Med. Surg.* **2002**, *20*, 241.
(5) [illegible] A. P.; [illegible] [illegible] E. O.; [illegible] A. R. *J. Proteome Res.* **2002**, *1*, 475.
(6) [illegible] E. G.; [illegible] N. H. *Nature* **2001**, *409*, 1083.
(7) [illegible] C. J.; [illegible] D. E. *Nature* **2002**, *417*, 159.
(8) [illegible] D. S.; [illegible] E. K., Jr.; [illegible] K. L.; [illegible] H.; [illegible] C. S.; [illegible] S. J.; [illegible] D. F.; [illegible] C. R.; [illegible] R. N. *Science* **1996**, *273*, 924.
(9) [illegible] R. L.; [illegible] L. A. *Meteorit. Planet. Sci.* **2002**, *37*, 1057.
(10) [illegible] L. E.; [illegible] J. N.; [illegible] L. E.; [illegible] C. [illegible] H.; [illegible] *Science* **1999**, *286*, 90.
(11) [illegible] J. O.; [illegible] D. Q.; [illegible] [illegible] L.; [illegible] D. J. *Proc. Natl. Acad. Sci. U.S.A.* **2000**, *97*, 11 511.
(12) [illegible] E. O.; [illegible] N. *Proc. Natl. Acad. Sci. U.S.A.* **1998**, *95*, 8274.
(13) [illegible] H.; [illegible] M. D.; [illegible] N.; [illegible] S. K.; [illegible] F. L.; [illegible] E.; [illegible] P.; [illegible] M.; [illegible] E. O.; [illegible] R. N. *Geochim. Cosmochim. Acta* **2001**, *65*, 63.
(14) [illegible] K. L.; [illegible] D. S.; [illegible] S. J.; [illegible] T. O.; [illegible] A. E.; [illegible] C. C.; [illegible] A.; [illegible] E. K., Jr.; [illegible] C. S. *Geology* **1998**, *26*, 1031.
(15) [illegible] A. P.; [illegible] M. *Biomed. Tech.* **1999**, *44*, 290.
(16) [illegible] A. P.; [illegible] R. P. *J. Proteome Res.* **2002**, *1*, 111.
(17) [illegible] A. P. [illegible] 2001, [illegible] TX, *NASA Conference Publication*, CP-2002−210786, 78−83, 2002.
(18) [illegible] A. P.; [illegible] A. L. B.; [illegible] A. R.; [illegible] R. P.; [illegible] H. T. *J. Clin. Laser Med. Surg.* **2001**, *19*, 29.
(19) [illegible] [illegible] S. *Neurol. Res.* **1998**, *20*, 470.
(20) [illegible] J. T.; [illegible] M. M.; [illegible] P.; [illegible] M. T. T.; [illegible] E. [illegible] M.; [illegible] N. T.; [illegible] H. T. *Proc. Natl. Acad. Sci. U.S.A.* **2003**, *100*, 3439.
(21) [illegible] A. P.; [illegible] R. P. *NanoLett.* **2003**, *3*, 19.
(22) [illegible] H.; [illegible] J. G.; [illegible] E. A. *Nature* **2000**, *405*, 299.
(23) [illegible] J. M. *Nature* **2001**, *412*, 442.
(24) [illegible] N.; [illegible] M. A.; [illegible] J. T.; [illegible] E. O. *Antimicrob. Agents Chemother.* **2002**, *46*, 2077.
(25) [illegible] A. P.; [illegible] E. O. *Crystal Growth Des.* **2002**, *2*, 563.
(26) [illegible] E.; [illegible] A. F.; [illegible] A. *Lasers Surg. Med.* **1985**, *5*, 31.
(27) [illegible] N.; [illegible] M.; [illegible] K.; [illegible] K.; [illegible] E. O. *Kidney Int.* **1999**, *56*, 1893.
(28) [illegible] E. O.; [illegible] N.; [illegible] M. A.; [illegible] J. T. *Curr. Opin. Nephrol. Hypertens.* **2001**, *10*, 445.

PR034005H