MOLECULAR COLONIES: A PLAUSIBLE FORM OF COMPARTMENTALIZATION IN THE RNA WORLD

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Oparin was the first who realized that no evolution in the prebiotic world was possible without a competition and hence compartmentalization, some form of segregation of biomolecules from the environment [1]. His 'coagulates' (bits of a gel) and then 'coacervates' (colloid vesicles) were the first models of primitive cells. The need for compartmentalization is now commonly aknowledged [2-4].

Most modern theories consider liposomes as a pre-cellular form of compartmentalization. Liposomes are capable of spontaneous proliferation by incorporating new lipid micelles or molecules followed by breaking down into smaller vesicles. Moreover, it was shown that if a liposome was loaded with RNA, NTPs, and a replicase, the liposome division was coupled with RNA replication [5], which is reminiscent of cell division. However, in using liposomes as cell analogs there are a lot of yet unresolved problems, of which the most serious is that lipid membrane is hardly permeable to hydrophilic low molecular weight compounds, such as nucleotides or their precursors needed for the synthesis of biopolymers, which have to enter the cell from the environment. Even passive diffusion of such compounds is very slow, with the half time required for the transmembrane equilibration exceeding 10 h [6]. This makes the rate of intra-liposome synthesis of nucleic acids unacceptably low even at the extra-liposome concentration of nucleotide substrates as high as 5 mM, which can hardly be expected of the ‘primordial soup’.

Another form of compartmentalization of biochemical reactions could be molecular colonies that form when RNA or DNA are amplified in a porous solid medium [7,8]. The synthesized copies remain nearby the parental template, and make up a spherical cluster of molecules which resembles a cell. The principal difference from the cell is that molecular colony is not enveloped with a lipid membrane. Nevertheless, compartmentalization is achieved as long as the colony is separated from the surrounding medium. It was shown that all basic biochemical reactions needed for the reproduction and functioning of a living cell, such as RNA or DNA replication, transcription, and even translation, can occur in molecular colonies. Moreover, molecular colonies were shown to be able of linking the phenotype to genotype which is needed for the natural selection and evolution.

References

[1] A. I. Oparin, The Origin of Life. Moscow Worker publisher, Moscow, 1924 (in Russian). English translation: A. I. Oparin, The Origin and Development of Life (NASA TTF-488). D.C.L GPO, Washington, DC, 1968.
[2] W. Gilbert, S. J. de Souza, Introns and the RNA world, in The RNA World, 2nd ed., eds. R.F. Gesteland, T. Cech and J.F. Atkins, CSHL Press, Cold Spring Harbor, NY, 1999, pp. 221-231.
[3] J. W. Szostak, Constrains on the Sizes of the Earliest Cells, in Size Limits of Very Small Microorganisms. National Academy Press, Washington, DC, 1999, pp. 120-125.
[4] A. S. Spirin Mol. Biol. (Moscow), 2005, 39, 550.
[5] T. Oberholzer, R. Wick, P. L. Luisi, and C. K. Biebricher, Biochem. Biophys. Res. Commun., 1995, 207, 250.
[6] S. S. Mansy, J. P. Schrum, M. Krishnamurthy, S. Tobé, D. A. Treco, and J. W. Szostak, Nature, 2008, 454, 122.
[7] A. B. Chetverin, H. V. Chetverina, and A. V. Munishkin J. Mol. Biol., 1991, 222, 3.
[8] A. B. Chetverin, and H. V. Chetverina, Prog. Nucleic Acid Res. Mol. Biol., 2008, 82, 219.