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Review

Hypothesis: the origin of life in a hydrogel environment

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Abstract

A hypothesis is proposed that the first cell(s) on the Earth assembled in a hydrogel environment. Gel environments are capable of retaining water, oily hydrocarbons, solutes, and gas bubbles, and are capable of carrying out many functions, even in the absence of a membrane. Thus, the gel-like environment may have conferred distinct advantages for the assembly of the first cell(s).

Keywords: Assembly; Bacteria; Cell; Clays; Cytoplasm; Division; Earth; Evolution; Growth; Hydrogel; Life; Membrane; Origin; Water

Contents

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1. Introduction

The origin and evolution of life have been long debated, with fundamental questions still unresolved. What, for example, were ancient life's most common single-celled forms (Schopf, 1999)? For what biological, chemical, or physical life signatures ought one to be searching (Bebié and Schoonen, 1999; Bashkin, 2002; Cairns-Smith, 1985, 2001; Deamer, 1997, 1992; Des Marais and Walter, 1999; Gold, 1992, 2001; Ingber, 2000; Morchio and Traverso, 1999; Morita, 1999; Nilson, 2002; Segre et al., 2001; Trevors, 2001a, b, 2002a, b, 2003a–c; Trevors and Abel, 2004; Trevors and Psenner 2001; Wächtershäuser, 1997)? Where should one look for ancient life remnants—in thermal springs, deep ocean vents, subsurface cores, deep hot oily subsurfaces (Gold, 1992, 2001) where water and oil form interfaces, or in available extraterrestrial samples?

In searching for answers to these questions, an implicit presumption is often made that the cell is an aqueous suspension of solutes. The pre-cell, then, is also considered to be an aqueous suspension, eventually surrounded by a membrane to become a cell. However, it is known that the cell is a gel (Pollack, 2001). With the cytoplasm treated as a gel rather than as an aqueous suspension, a question worth considering is whether the various conundrums that have limited progress in understanding the origin of life and the genetic instruction set might be better resolved.

We propose that a primitive hydrogel was a more suitable environment for the assembly of pre-cells, and then cells capable of growth and division. Gels, for example, retain their integrity even in the absence of a membrane. Primitive organelles, nutrients, ions, proteins and nucleic acids could remain ordered and in continuous, close molecular physical proximity within the gel without the danger of dissipating, as it would in a strictly aqueous environment with free diffusion. Hence, the question of how the pre-cell with no membrane and a very small mass could retain its integrity, need not be an issue with the cytoplasm viewed as a cohesive gel. Further, many basic functions performed by the cell or pre-cell are capable of being carried out by gels themselves, as we elaborate below.

2. The hydrogel environment: superior to a liquid environment for the origin of life?

Although gels are employed for numerous functions from absorbing urine in disposable diapers, and for immobilizing enzymes and cells, to controlling drug release in time-release pharmaceuticals, there is no agreed-upon definition of a gel. A textbook definition is that the elastic modulus is greater than the viscous modulus: unlike liquids, gels do not flow as a result of steady shear. A phenomenological definition is that gels are solid or solid-like materials that