CREATR: a complex, multistage model for the origin of life

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INTRODUCTION

We offer for consideration the following multistage model for the arising of protocells capable of metabolism, statistical reproduction and replication of hereditary information. The model which we term Complex Repeated Encapsulation of Attached Template Replicators (CREATR) was inspired in part by Freeman Dyson's "double origins" hypothesis (Dyson, 1999). We hypothesize a conceptual natural system that repeatedly generates a large number of Dyson's "garbage bags" whose contents consist of non-random collections of "dirty water". Figure 1 maps this conceptual "protocell factory" whose stages are informed by a number of researchers' recent findings.

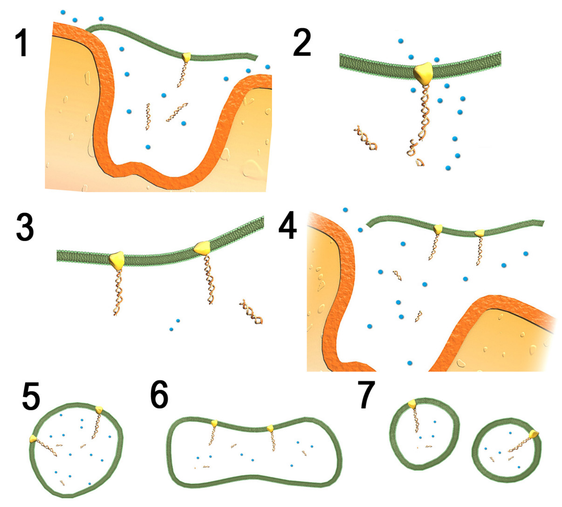

Fig. 1. Cartoon model of the stages of the CREATR model.

1. Membrane-Enclosed Micropore

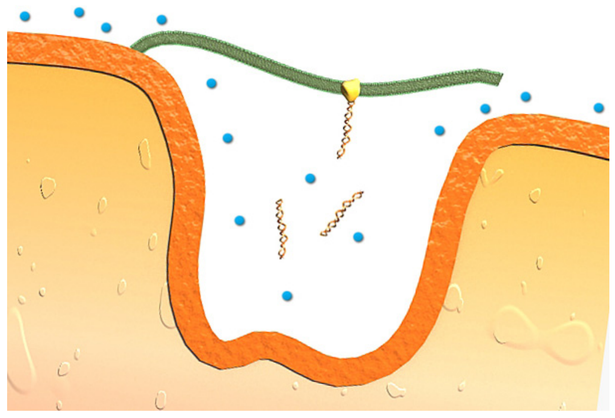

Fig. 2. Micropore environment enclosed by a permeable membrane.

Figure 2 depicts a pinhole or micropore in a submerged rock face in the vicinity of a hydrothermal vent, surface geyser, or shoreline environment over which has formed a lipid membrane creating a permeable encapsulation promoting the concentration and reaction of bio-important molecules. This scenario is based in part on the hydrothermal pore work of (Baaske et al., 2007).

2. Membrane-Attached RNA

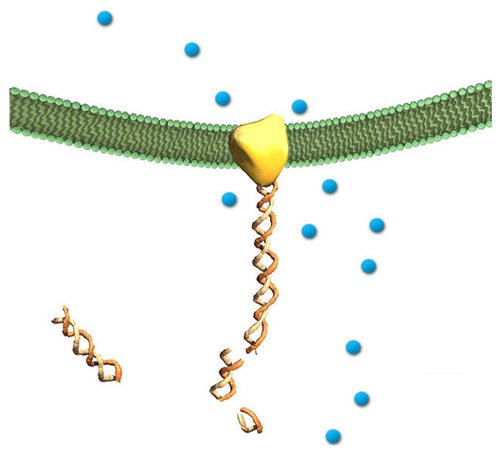

Fig. 3. Binding of RNA complex to lipid membrane.

Figure 3 illustrates an RNA complex binding to the membrane creating a disruption that can act as a channel based on the experimental results of (Vlassov et al., 2001). The formation of long RNA complexes within multilamellar compartments may have been made possible by the wet-drying cycles described by (Deamer, 2009). The key result of this stage is the close association of RNA complexes with the covering membrane.

3. Replication of RNA

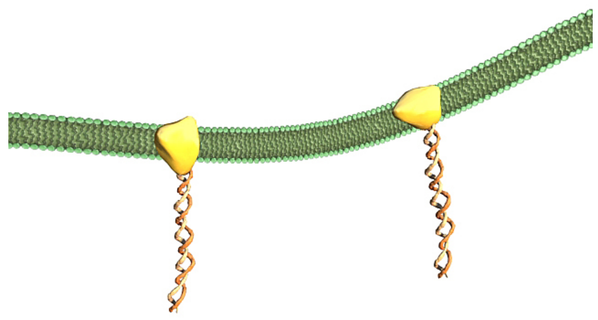

Fig. 4. Replication of RNA complexes.

Figure 4 shows the result of templated replication of the membrane-attached RNA complex driven by the passage of nucleotides or other significant molecules crossing into the micropore at the disruption channel close to the anchor point (Figure 3). A number of such RNA complexes may be replicated through the action of an RNA polymerase ribozyme and random mutations may provide some diversity of accidental active functions valuable at a later stage.

4. Detaching of Membrane

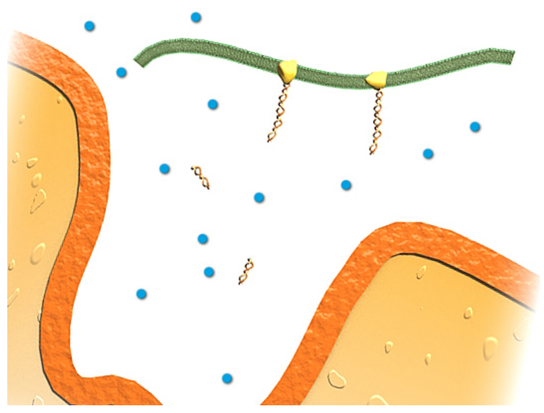

Fig. 5. Detaching of membrane covering from micropore along with release of concentrated micropore contents.

Figure 5 depicts the moment when a physical process such as wave action detaches the membrane complex from the micropore and along with it the affixed RNA complexes and other pore contents. It is important to note that the original micropore would again be free to support new membrane formation and partial containment. This section of membrane would go on to form a closed encapsulation (see 5. below). Thus a population of micropores would therefore act as a sort of *combinatorial chemistry factory* to produce numerous encapsulations, each with different contents but possibly somewhat similar membranes from each individual micropore. Therefore, a potentially large population of vesicles encapsulating a variety of RNA complexes and molecular content would be continually released into a local region.

5. Vesicle Encapsulation

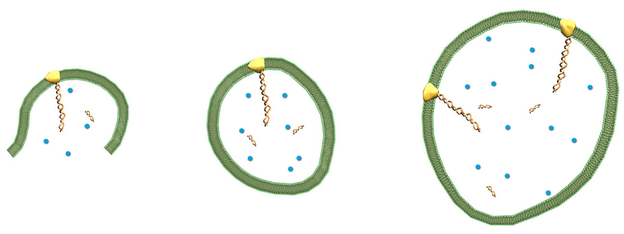

Fig. 6. Encapsulation of micropore membrane forming vesicle.

Figure 6 shows the detached membrane complex which may quickly close to form a full encapsulation or vesicle. Vesicles may contain just a few elements (center) or two or more anchored RNA complexes (right). Returning to Dyson's reasoning with reference to Oparin and Lancet these garbage bags may also contain catalysts which, statistically rather than exactly, might reproduce the contents of the vesicle. These same catalysts in concert with active functions on the RNA complexes might also mediate a sort of metabolism driven across the membrane at the disruption channels.

6. Reproduction & Origin of Life

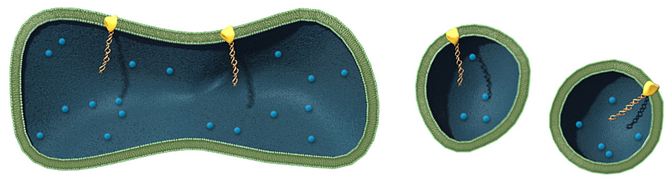

Fig. 6. Growth and division of vesicle into two daughter protocells.

As the "protocell" vesicle grows through the addition of lipid from the local environment (Figure 6, left), the elongation that precedes a division into daughter protocells (right) (Hanczyc and Szostak, 2004) may force attached RNA complexes apart so that they are statistically more probable to end up in a separate daughter protocell. Catalysts may statistically reproduce the other interior populations to a sufficient extend to "seed" the daughter cells. Dyson points out that if the probability of at least one daughter protocell containing a complete self-reproducing population of molecules is greater than one half, then multiple functional daughters will result in a chain reaction producing a "line" of statistically reproduced protocells. Natural selection as described by Darwin would come into effect even in this inexact statistical reproduction of protocell lines. Competing lines would over time refine the mechanisms of their catalysts, the effectiveness of the channels, and the regulatory and replicating capability of the RNA complexes.

In reviewing this model, Deamer asked how the encapsulated molecules might control the tendency for larger vesicles to break down into smaller ones at a specific time, thereby regulating the early process of mitosis? If a given line of protocells eventually dies off there will always be the upstream micropore factory able to produce a new combination to "try again". Broken parts from failed protocells would be recycled by micropores or combine with other fragments to form new protocells in an early form of sexual recombination. When a protocell line persists forever, then life's origin has occurred.

Call for Collaboration

The authors invite input from the community as to the viability of this model with respect to the plausibility of individual stages and experiments to test whether lipid membranes can form over micropores and subsequently become detached to form vesicles.

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