

Prebiotic Chemistry From Simple Amphiphiles To Protocell Models

Hardcover

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Protocells and the Origin of Life
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Model Towards Structural and Functional Protocell Evolution
Computational Models for the Formation of Protocell
Structures
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the first comprehensive general resource on state of the art protocell research describing current approaches to making new forms of life from scratch in the laboratory protocells offers a comprehensive resource on current attempts to create simple forms of life from scratch in the laboratory these minimal versions of cells known as protocells are entities with lifelike properties created from nonliving materials and the book provides in depth investigations of processes at the interface between nonliving and living matter chapters by experts in the field put this state of the art research in the context of theory laboratory work and computer simulations on the components and properties of protocells the book also provides

perspectives on research in related areas and such broader societal issues as commercial applications and ethical considerations the book covers all major scientific approaches to creating minimal life both in the laboratory and in simulation it emphasizes the bottom up view of physicists chemists and material scientists but also includes the molecular biologists top down approach and the origin of life perspective the capacity to engineer living technology could have an enormous socioeconomic impact and could bring both good and ill protocells promises to be the essential reference for research on bottom up assembly of life and living technology for years to come it is written to be both resource and inspiration for scientists working in this exciting and important field and a definitive text for the interested layman

how life can emerge in a lifeless environment is one of the major open scientific challenges this book pays particular attention to self organization phenomena that might have led to the appearance of the first protocells i e cell like structures much simpler than present day cells endowed with some primitive kinds of metabolism and heredity after a brief description of the known facts and main hypotheses mathematical and computational models of protocells are discussed they should complement laboratory experiments allowing rapid explorations of the dynamical properties of several alternative types of protocell architectures given the great uncertainties about the actual origin of life it seems impossible to provide a detailed and complete reconstruction of the first life forms it is therefore necessary to identify plausible pathways highlighting the main physical and chemical processes towards life that can take place generic models which are abstract enough to encompass different specific hypotheses are particularly relevant as they allow one to identify properties which are common to several different detailed scenarios they are widely discussed and a particular case is described in detail namely that of synchronization between the rate of molecular replication and that of reproduction of the whole protocell which is a necessary condition for sustainable growth of a population and a prerequisite for further evolution using generic models it is shown that such synchronization spontaneously emerges in successive generations under very general assumptions the book also contains extensive descriptions of the emergence of long polymers of autocatalytic sets and of the interactions between protocells and their environments the book is not meant only for specialists but also for scientists working in different fields as well as for laymen with an interest in science it requires a basic knowledge of chemistry and biology and an interest in simulation models

compartmentalization is critical in cells this dissertation is aiming to better understand cellular organization by investigating the development of protocell and synthetic cell models by combining liquid liquid phase separation llps with lipid the interaction between membrane bound and membraneless organelles represents a critical yet understudied aspect of cell biology as these distinct compartmentalization strategies coexist and likely work together to regulate crucial cellular processes understanding these interactions is particularly challenging in living cells due to their inherent complexity therefore developing simplified model systems both protocells to study potential evolutionary pathways and synthetic cells to understand modern cellular functions allows researchers to systematically examine how different types of compartmentalization influence cellular activities these models provide controlled environments to investigate fundamental principles that would be difficult to study in intact cells while potentially offering insights into disease mechanisms as disruptions in membraneless organelles have been linked to various conditions including neurodegenerative diseases through three main chapters this work demonstrates how integrating these components can overcome limitations of individual systems while providing insights into potential prebiotic compartmentalization mechanisms chapter 2 studies prebiotically plausible compartmentalization mechanisms include membrane vesicles formed by amphiphile self assembly and coacervate droplets formed by liquid liquid phase separation both types of structures form spontaneously and can be related to cellular compartmentalization motifs in today s living cells as prebiotic compartments they have complementary capabilities with coacervates offering excellent solute accumulation and membranes providing superior boundaries in this work we describe protocell models constructed by spontaneous encapsulation of coacervate droplets by mixed fatty acid phospholipid and by purely fatty acid membranes coacervate supported membranes formed over a range of coacervate and lipid compositions with membrane properties significantly impacted by charge charge interactions between coacervates and membranes notably vesicles formed by coacervate templated membrane assembly exhibited dramatically different permeability characteristics compared to traditional fatty acid or blended fatty acid phospholipid membranes without a coacervate interior particularly in the presence of Mg^{2+} ions while fatty acid and blended membrane vesicles were disrupted by 25 mM $MgCl_2$ the corresponding coacervate supported membranes remained intact and impermeable to externally added solutes this enhanced membrane robustness enabled a primitive metabolic like demonstration fluorescein diacetate fda hydrolysis where the neutral fda molecule could diffuse into the protocell and the coacervate interior catalyzed its conversion to fluorescent fluorescein

which was subsequently retained within the hybrid protocell chapter 3 investigates membrane heterogeneity in hybrid protocells that combine lipid vesicles with coacervate interior as heterogeneous membranes are considered more prebiotically plausible having likely emerged through either endogenous synthesis or exogenous delivery on early earth it is crucial for understanding how early cells might have adapted to varying environmental conditions the study finds that mixed composition membranes containing glycerol monooleate or cyclophospholipids show enhanced stability under acidic conditions compared to pure oleic acid membranes suggesting potential evolutionary advantages of membrane heterogeneity in addition both pure and mixed membrane for hybrid protocell with coacervate interiors showed selective permeability allowing smaller molecules like fluorescein to pass while restricting larger more charged molecules notably mixed membranes displayed variable permeability levels across different structures suggesting potential functional diversity and evolutionary adaptability chapter 4 explores how newly formed phase separating proteins from cell free transcription and translation txtl interact with pre existing systems in synthetic cell models using rgg gfp rgg as a model protein we successfully produced proteins in bulk solution and within pre existing tandem rgg droplets observing reduced efficiency in the latter our investigation examined lipid protein interactions through various approaches including electrostatic interactions specific bio recognition and natural lipid mixtures we discovered that txtl buffer components significantly altered droplet morphology and size distribution over time while complete membrane formation around protein rich droplets proved challenging the research provides important insights into the complex interactions between phase separating proteins lipid membranes and cellular protein expression mechanisms advancing our understanding of synthetic cell design together this dissertation advances our understanding of cellular compartmentalization while providing new approaches for developing more sophisticated protocell and synthetic cell models the findings have implications for origin of life research and the development of synthetic cellular systems

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