COACERVATE SYSTEMS AND ORIGIN OF LIFE

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Abstract. Hydrophilic coacervate systems consist of coacervate drops (0.5–640μ in diameter) and liquid. The most molecules are cooperated into the drops. Defects of such systems and drops are instability. Stable protein-nucleic-acid carbol-hydrate drops are studied. Enzymatical oxidized reactions were fulfield by the peroxidase (1.11.1.7) and the polyphenoloxidase (1.10.3.1) and its substrates (phenol and other ones) in coacervate systems. The drops are getting stable by the oxidized compounds quinones and others. The quinone content of individual drops (more than 5000 drops) was found by means scaning Cytospectrophotometer SIM. The limit of analysis 1×10^{-13}–10^{-14} g, the errors 3 % of the value found. The mathematical equations of the dependence both the size of drops and the content of oxidized compounds were calculated. The structure of stable drops was investigated in electronic microscope. The drops bound one to other by means bridges or hills, and formed colonia. We proposed that different stability of drops, especially stable ones, and colonia are interesting phenomena for the Origin of Life.

1. Introduction

The origin of life and the artificial synthesis of life are among the great problems of science. According to A. I. Oparin's theory of the origin of life (Oparin, 1966) ther were some initial stages of chemical evolution during the prebiological period. The association of molecules, however, could have taken place in microspheres (Fox, 1968), lipoprotein bubbles and coacervate drops (Oparin, 1966). The place of coacervate drops and others of procells models in the evolution of matter is shown in Figure 1 (Evreinova, 1972). Coacervate systems were studied by H. G. Bungenberg de Jong at the beginning of this century. Now, more than 250 hydrophilic coacervate systems are known. They may consist of two or more different molecules. The chemical classification of coacervate systems was published (Evreinova, 1966). The hydrophilic coacervate systems consist of drops (0.5–640 μ in diameter) and equilibrium liquid. There are coacervate drops in protoplasm of living cells. The common property of any coacervate system is the cooperation or association of molecules in the coacervate drops. Only a relatively few polymer molecules exist in the equilibrium liquid; drops may absorb other molecules from equilibrium liquid and the property of drops is used in practice. The most of coacervate drops are unstable ones (Evreinova, 1966).

The purpose of this paper is to show how the enzymatic reactions in coacervate systems affects the stability and the structure of drops.

2. Experimental

Coacervate systems were obtained from aqueous solutions of Histon, DNA, Gum-Arabic (0.5 to 1%) and enzymes (0.03 mg ml^{-1}) Poly phenoloxidase (1.10.3.1)

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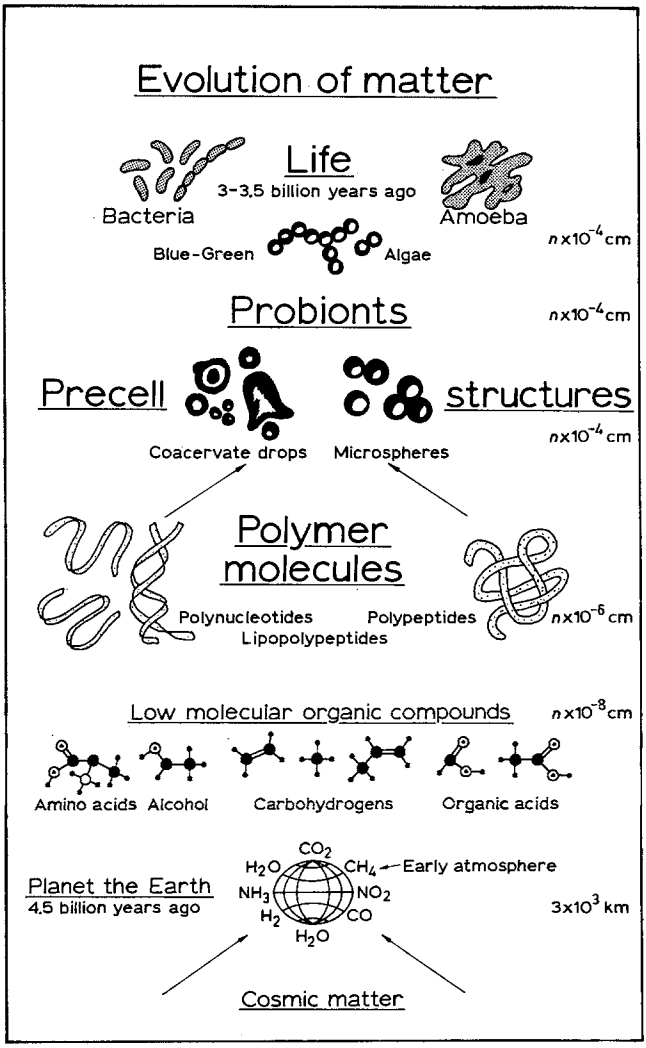


Fig. 1. Evolution of matter and Origin of Life.

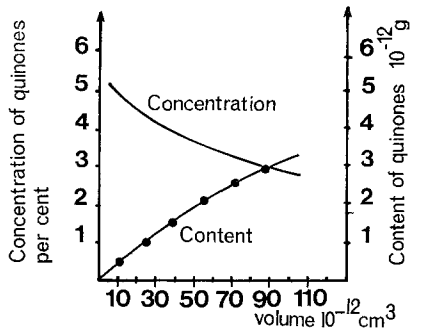
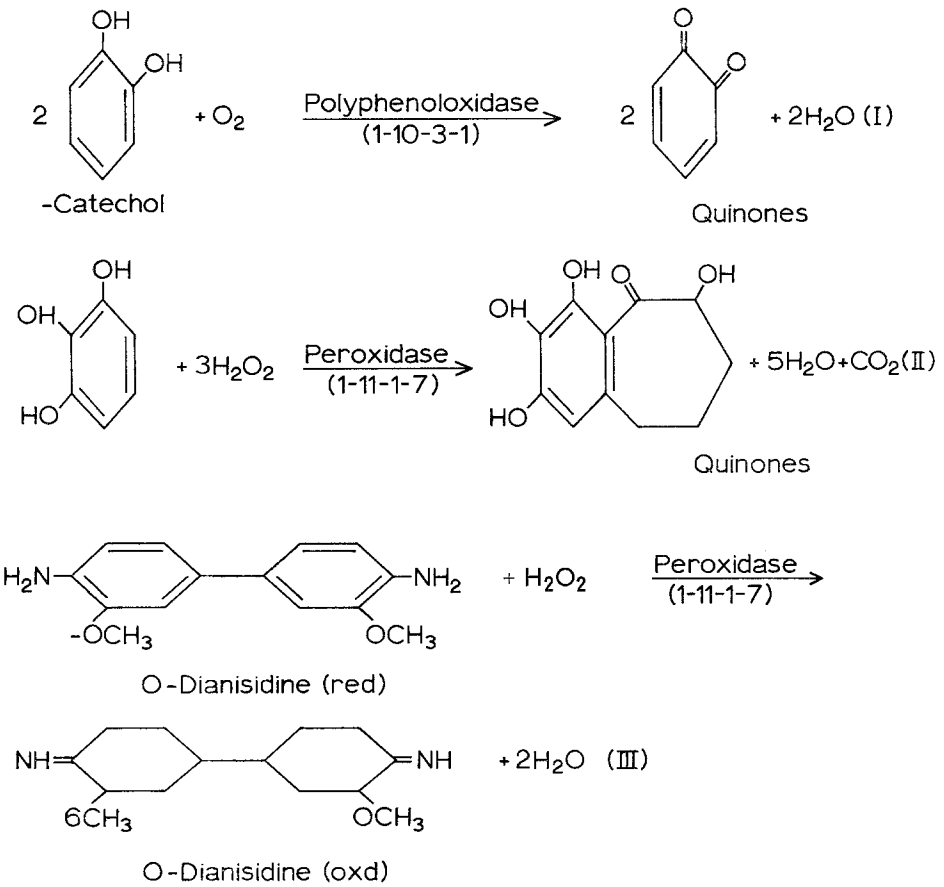


Fig. 2. The content (–·–·–) and the concentration (—) of quinones in individual drops of coacervate system: Peroxidase-Histon-Gum Arabic-Quinones (pH = 6.0).

Peroxidase (1.11.1.7) and their substrates (Phenols, H_2O_2, O-Dianisidine-red). The coacervate drops were formed at the pH = 6.0 and at the temperature 16° to 30°. The size and the oxidized compounds content of individual drops were found by means of a scanning recording cytspectrophotometer SIM. The limit of the analyses was 10^{-13} to 10^{-14} g of oxidized compounds. The error was 2.5% of the value found. Details of composition of coacervate systems and optical methods and calculations for drops have been reported (Evreinova *et al.*, 1972). More than 5000 individual drops were measured. The structure of drops was investigated in electronic microscope (Evreinova *et al.*, 1973). The magnification was equal to 5000 to 50000. Some of the results are illustrated in Figures 2 and 3 and Table I, and in chemical, mathematical Equations (I–V).

The Enzymatic Reactions
in Coacervate Systems



Figs. 3A—D. Coacervate drops in electronic microscope: (A) Coacervate drop of Histon-DNA; (B) The part of coacervate drop of Peroxidase-Histon-DNA-Quinones; (C) Coacervate drops-Peroxidase-Histon-DNA-O-Dianisidine (oxd): (D) Coacervate drops-Peroxidase-Histon-Gum Arabic-Quinones.

TABLE I

The content of oxidized compounds in individual coacervate drops

No.	Diameter 10^{-4} cm	Volume 10^{-12} cm^3	Oxidized compounds	
			Weight 10^{-12} g	Concentration %
Peroxidase - Histon - Gum Arabic - Quinones pH = 6.0				
1	4.400	44.604	1.803	4.04
2	4.967	64.126	2.418	3.77
3	5.27	76.81	2.748	3.57
4	6.28	129.56	3.535	2.72
Peroxidase - Histon - DNA - Quinones pH = 6.0				
5	2.76	11.01	0.911	8.27
6	3.20	17.22	1.089	6.32
7	4.62	51.70	2.357	4.55
Peroxidase - Histon - Gum Arabic - O-Dianiside (oxd) pH = 6.0				
8	3.44	21.31	0.160	0.75
9	3.99	33.31	0.220	0.66
10	4.62	51.70	0.314	0.60
11	5.90	107.65	0.597	0.55
Peroxidase - Histon - DNA - O-Dianisidine (oxd) pH = 6.0				
12	2.56	8.81	0.095	1.07
13	3.14	16.21	0.162	0.99
14	3.89	30.77	0.255	0.83
15	4.40	44.69	0.295	0.66

3. Results and Discussion

Drops in trivial coacervate systems settle on the bottom of the vessel and disappear; they convert a thin layer. For example, the drops which consisted of serum Albumin-Histon disappear in 30 min.

The first stable coacervate drops were prepared in 1968 (Evreinova and Bailey, 1968). These drops also settle, but they do not disappear and are stable for four years or more. The stability of drops was reached due to enzymatic reactions. The drops containing oxidized compounds are stable. The content of quinones and O-dianisidine (oxd) in individual drops were 0.003 to 6%. Only a relatively few molecules of oxidized compounds are in equilibrium liquid (Evreinova *et al.*, 1971). There are correlations both in the size and in the concentration of oxidized molecules of drops. Tiny drops contain a high content oxidized compounds per unit volume than large ones (Table I). The results with polyphenoloxidase coacervate systems were published in 1968–1971. The same phenomena takes place for the total dry mass content of polymer molecules in coacervate drops (Evreinova, 1966).

There were many experimental dates (more than 1000 for each coacervate system). That's why it was possible to calculate the content and the concentration of oxidized

compounds in any drop by the mathematical equations (for example IV–V, and Figure 2).

Peroxidase - Histone - Gum Arabic - Quinones

$$y = 0.089 + 0.050x - 0.00017x^2 \quad \text{(IV)}$$

$$y_1 = 4.805 - 0.019x + \frac{4.6}{x} \quad \text{(V)}$$

y : the content of quinones $n \times 10^{-12}$ g
y_1: the concentration of quinones %
x : volume of a drop -10^{-12} cm^3.

The structure of coacervate drops in electronic microscope is shown in Figure 3A, B, C, D. The stability and the structure of drops are changed by the enzymic reactions. The surfaces of unstable drops (Histon-DNA and others) are homogeneous. There are many hills on the surfaces of the stables drops (Histon-DNA-quinones and others). Stable drops are bounded by the hills and the bridges and formed colonia. According to Buvet's and Toupance's theory (Buvet, 1971) the first step was a non-enzymic activation of substances; the second step was their oxidation for the prebiological stages. We proposed the stabilisation of molecules in coacervate drops and the formation of colonia are of some interest for solving origin of life; and a number of biological items.

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