Metric Similarity of Dynamic Commutation Processes *In Situ* and *In Vitro*

S. V. Stovbun, A. A. Skoblin, A. M. Zanin, A. I. Mikhailov, V. A. Tverdislov*, E. E. Bragina, Yu. M. Rybin***, I. M. Ageev***, and G. G. Shishkin*****

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The dynamics of string growth was studied in model homochiral solutions of biomimetics, trifluoroacetylated amino alcohols (TFAAA) in heptane, water, and inverted heptane-water emulsion. In heptane and water, a thick (~1 μ in diameter) string had a crown of thin strings on its growing terminal and these thin strings effectively adsorbed dissolved TFAAA. In emulsion, the strings grew inside the water droplets, in which this TFAAA cannot be solved, presumably due to transport of TFAAA molecules from heptane into water in the surface layer surrounding the string. Applications of these phenomena to *in vivo* cell commutation were discussed.

Key Words: *chirality; strings; biomimetics; cell commutation*

Spontaneous formation of anisometric structural elements, strings, in model homochiral solutions of biomimetics [1,3,5,6] allows physicochemical simulation of biological media as anisometric fluids [10], processes of information and force commutation of microbiological objects [2,7,8], and biological cells as integral objects [9]. We studied the dynamics of string formation in biomimetic solutions in order to create metrically similar physicochemical models of dynamic processes providing commutation of microbiological objects.

MATERIALS AND METHODS

Homochiral solutions of trifluoroacetylated amino alcohols (TFAAA) were studied: TFAAA-1 with a concentration of 0.4 mg/ml in heptane and 1 mg/ml in heptane-water mixture (90% heptane and 10% water) forming inverted emulsion; TFAAA-2 (hydrogelator) with a concentration of 10 mg/ml in water. TFAAA were synthesized at Laboratory of Stereochemistry, Institute of Chemical Physics (Head: Prof. R. G. Kostyanovsky). The method for obtaining and structural formulas of TFAAA have been previously described [8,11]; structural formula of TFAAA-1 is presented in Figure 1 (*a*). Heptane of 99.9% purity (Khimmed) was used. TFAAA solutions were put into closed flat capillaries, which precluded solvent evaporation. Nonequlibrium conditions initiating kinetic processes were created in the samples; to this end, the samples were heated to 70°C using Peltier elements (TFAAA-1 solutions) or a flow of hot air from a hairdryer (TFAAA-2 solutions) and then cooled at ambient temperature. The processes during cooling of the samples were recorded on a computer-aided optical testing unit based on a BX51 Olympus microscope (Olympus Corporation) for TFAAA-1 solutions and on a Jena optical microscope (Carl Zeiss) for TFAAA-2 solutions.

Continuous VERO cell culture was examined under a CamScan S2 scanning electron microscope

N. N. Semenov Institute of Chemical Physics, the Russian Academy of Sciences; *Physical Faculty, M. V. Lomonosov Moscow State University; **A. N. Belozersky Institute of Physicochemical Biology, M. V. Lomonosov Moscow State University; ***Moscow Aviation Institute (State Technological University). ***Address for correspondence:*** s.stovbun@chph.ras.ru. S. V. Stovbun

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(Cambridge). The preparations were prepared as described previously [7].

RESULTS

The dynamics of string growth in TFAAA-1 solution in heptane was recorded; the strings were ~1 μ in diameter (Fig. 1).

A clearly seen crown of thinner strings originated from the tip of the string, in fact from the same site (vanishing point) within a solid angle ~π. Thin strings of submicroscopic diameter measured in the vanishing point region (singularity) into the microscopic string, forming a spiral supramolecular structure (Fig. 6 in [3] and Fig. 3 in [4]). As the solution cooled, the terminals of thin strings moved forwards, that is, the strings grew. The vanishing point also moved forward following the thin string growth. As a result, the length of the thick string increased, while the crown moving forward remained of about the same size. The velocity of string growth in the sample was 3 to 7 μ/sec. The presence of the crown was presumably explained by electrostatic repulsion of the thin string terminals at the stage of their formation in the vanishing point region.

A similar picture was observed during cooling of TFAAA-2 water solution. However, the basic qualitative difference was self-similarity: the crown strings branched forming crowns of their own. The growth rate of various strings in TFAAA-2 water solutions varied from 5 to 15 μ/sec. It is noteworthy that structures very much similar to crowns were observed as anisometric elements of the commutating cells periphery (Fig. 2). The metric similarity detected *in vivo* and *in situ* suggested an explanation of the mechanisms of formation of these heretofore not identified morphological structures.

String growth from heptane into water droplets was observed in inverted heptane-water emulsions (water droplets dispersed in heptane medium). The growth rate was no more than 1 μ/sec. The tip of the growing string narrowed and looked sharpened (Fig. 3). Small bright objects inside water droplets were most likely heptane droplets enveloped by TFAAA condensed on their surface [9]. It was previously found that TFAAA-1 is insoluble in water [5]. Videotaping demonstrated the string growth into water medium. It seemed to indicate a flow of TFAAA molecules into the water droplet in the thin surface layer surrounding the growing string.

This mechanism of growth of a thick string carrying a crown of thin strings on its growing tip may explain the high efficiency of concentrations of substances, dissolved in medium adjacent to the cell, by a limited number of string-like anisometric formations, as the crown of thin strings collected the dissolved substance much more effectively than the thick string terminal.

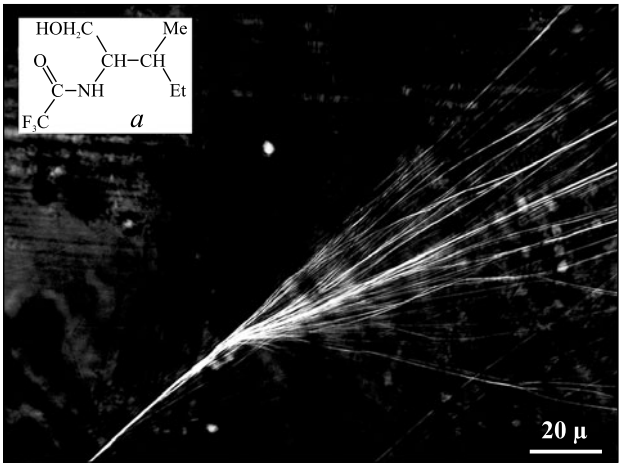

Fig. 1. Computer-aided optical testing unit. TFAAA-1 solution in heptane. Growing string. a) TFAAA-1 structural formula.

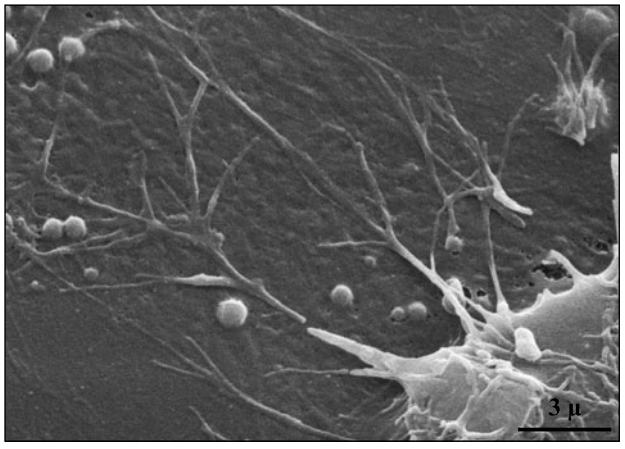

Fig. 2. Periphery of a VERO cell. Crown-like structures.

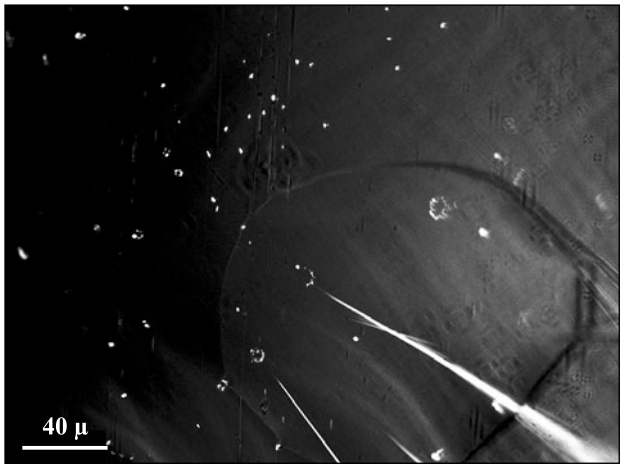

Fig. 3. Computer-aided optical testing unit. TFAAA-1 solution in heptane-water inverted emulsion. String growth from heptane into water droplet.

This pattern of thick string formation seemed to explain also the non-target π-commutation of microbiological objects, for example, in slight taxis. The growth of a string with a rather wide crown in the direction approximately corresponding to the direction towards the source of particles or quazi-particles will result, with high probability, in formation of a contact between at least one of the thin strings in the crown and the target, which might trigger the mechanism of the basal string pulling to the target.

The string growth from heptane into water (inverted emulsion) was presumably realized at the expense of hydrophobic/hydrophilic interactions with TFAAA amphiphilic molecules in the thin surface layer of the string cone substance plunged into water (Fig. 3). A similar molecular mechanism of absorption of amphiphilic molecules of membrane lipids can also lead to the formation of a point of growth of the cell commutation supramolecular structures [2,7,8].

Importantly, in case of the diffuse mechanism of substance concentration towards the tip of the growing isolated string, the estimated velocity of its growth (v) is inversely proportional to the string diameter [1]. Under conditions of the experiments discussed here, v~1 cm/sec for a thin string ~1 nm in diameter (which is comparable to TFAAA molecule size of ~0.3-0.5 nm) and v~10 μ/sec for the typical thick string ~1 μ in diameter correspond to the above velocities of string growth. However, in many cases thick string grow in a jump-wise mode with a velocity significantly higher than estimated growth velocity of a string of this diameter. This phenomenon is presumably explained by the presence of the crown. Really, due to the crown, each thin string in it can grow with a velocity corresponding to its diameter. Under these conditions, the totality of strings in the crown concentrate the substance from a greater volume of solution, this providing the eventual growth of the thick string at a velocity characteristic of thin strings constituting it and significantly more rapidly than estimated velocity for an isolated string of the corresponding diameter.

Hence, a series of dynamic processes essential for effective cell commutation has been simulated in homochiral model solutions of biomimetics.

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