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Kyoto University
Single-chain Characteristics in Giant DNA
— Larger Hydrodynamic Radius in Circular than that in Linear—

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Introd uction

The conformation of polymer chains in dilute solution is the subject of first chapter in polymer physics. The sizes of polymer, such as radius of gyration and hydrodynamic radius, are important fundamental characteristics because they can be examined with experimental methods. For an ideal circular chain, end-to-end distance \( L=0 \) by the definition, and the gyration radius \( R_g \) is deduced as [1]

\[
<R_g^2>_{\text{circular}} = b^2 N/12 = <R_g^2>_{\text{linear}} /2.
\]

where \( b \) is the segment length and \( N \) is the number of segments. This indicates that the gyration radius in an ideal circular chain is smaller by a factor of \( \sqrt{2} \) than that of linear chain of the same contour length. On the other hand, the hydrodynamic radius \( R_H \) in an ideal linear chain defined as the radius of hydrodynamically equivalent sphere is expected to be proportional and larger than the \( R_g \) as calculated from the Zimm model. Thus, it is expected that the hydrodynamic radius in circular chain is smaller than that in linear chain. As far as we know, experimental verification of such theoretical expectation has not been established yet, because it is difficult to synthesize monodisperse circular polymer. In this study, we measured hydrodynamic radius of linear or circular DNA with 106 kilo base pairs using fluorescence microscopy (FM). To examine hydrodynamic radius of giant DNA in dilute solution, FM is useful method because we can directly observe motions of individual molecules in dilute solution. It is found that, unexpectedly, the hydrodynamic radius of circular DNA is definitely larger than that of corresponding linear DNA.

Results and Discussions

Figure 1 (a) shows Brownian motion of individual DNA stained with fluorescence dye (DAPI) observed by FM as previously reported [2]. From the trails of the center of mass of the DNA molecule, we obtained the two-dimensional diffusion coefficient \( D \). The \( R_H \) is calculated from...
Figure 1: (a) Brownian motion trails as observed by FM. (b) the histograms of hydrodynamic radii.

\[ D \text{ based on the Stokes-Einstein relation } \]
\[ R_H = \frac{k_B T}{6 \pi \eta D}, \tag{2} \]

where \( k_B \) is Boltzmann constant and \( \eta \) is the viscosity of the solvent. The results of analysis of Brownian motion are summarized in Fig. 1 (b). It is clear that \( R_H \) in circular form (0.78 ± 0.30 \( \mu m \)) is at least 25% larger than linear form (0.58 ± 0.19 \( \mu m \)). This results show opposite trend to the above mentioned expectation from theoretical discussions. On the other hand, from fluorescence micrograph, it is found that radius of gyration in circular chain is smaller than that in linear chain. Thus it becomes evident that hydrodynamic radius exhibits the opposite trend to the radius of gyration. Our experimental results indicate that the "sizes" of circular and linear polymer chains are the still unsolved problem in polymer physics.

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References
