

Morphological Mechanics of Self-twisting Living Filaments: Coiling of *Physarum* Tube

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ABSTRACT

Spiral and helical structures are ubiquitous in nature and are particularly fascinating when they appear in biological processes such as growth, division, differentiation and locomotion. A thread of a true slime mold *Physarum polycephalum*, when hung in moist air, organizes a catenary under its weight. This is a typical phenomenon for viscous fluid ropes, but the difference becomes obvious when it lifts itself by actively contracting the surface of its body. Furthermore, when this length shortening is insufficient to overcome its gravitational force, the thread actively twists itself to make a loop and eventually develops a plectonemic supercoiling structure in which the filamentous plasmodium wraps around itself. This is characteristic in living filaments, and is only recently discovered in Ref. [1] independently of the classical observation by Kamiya and Seifritz 60 years ago [2]. It is clear that the acto-myosin layer in *Physarum* tube is responsible for this intriguing morphological dynamics, but the exact mechanism of observed self-twisting and plectonemic superstructure is highly nontrivial.

Motivated by this observation, we present a continuum mechanics approach to a self-twisting living filament powered by the contracting acto-myosin systems. We construct an elastohydrodynamic model of *Physarum* thread and reproduce its dynamical behavior using numerical simulations. We also develop a scaling-type argument to clarify a geometric condition of the onset of looping instability of a protoplasmic filament. In the experiment [1], a resulting plectonemic structure was always observed to be left-handed, while its underlying actin filaments forming right-handed helices. We address how this left-right relationship can be understood in terms of its topology, given appropriate torque boundary conditions. Biological implications of the coiling of *Physarum* thread will also be discussed.

REFERENCES

1. Noguchi T., Watanabe T., Kunita I., Wada H., Nakagaki T., Tanaka Y., "Coiling of Catenaries made from *Physarum* tube", preprint, 2014.
2. Kamiya N. and Seifritz W., "Torsion in a protoplasmic thread", *Exp. Cell. Res.*, Vol. 6, 1954, pp. 1-16.