Optical and Fluid-dynamical properties of a kind of Dinoflagellate

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Dinoflagellate

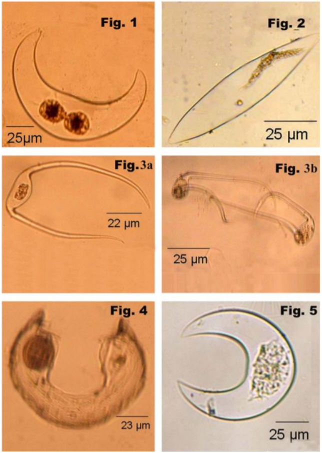

Figure: Some species of Dinoflagellates[1]

1

[1]Gul, Sadaf & Saifullah, Syed. (2009). Some rarely reported athecate dinoflagellates from North Arabian Sea. Pakistan Journal of Botany. 41. 3213-3218.

Dinoflagellate-p.lunula

Video [2]

[2] Jalaal, Maziyar et. al.(2020). Stress-Induced Dinoflagellate Bioluminescence at the Single Cell Level. Phys. Rev. Lett. 125, 028102

Dinoflagellate-p, lunula

- bioluminescence-scintillons
- photosynthesis-chloroplast

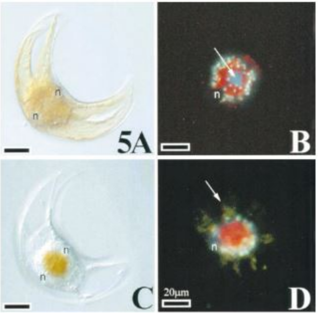

Figure: Circadian rhythm of the cell[3]

3

[3]Seo, Kyung Suk and Fritz, Laurence, Cell Ultrastructural Changes Corrolate With Circadian Rhythms in Pyrocystis Lunula(Pyrrophyta). J. Phycol. 36,351–358.

Model of Photosynthesis

Question: will the shape affects the photosyhthesis process?

Model 1: Averaged projected area(APA)
-all convex shapes have the same ratio of APA and SA
-for concave shapes like p.lunula, the ratio would be lower

Model 2: Ray optics to calculate the boost of light intensity caused by the difference in index of refraction
-Previous research[4] shows that cell body can act as lenses
-count the loss of light intensity. For unpolarized sunlight,

$$\frac{I_{reflection}}{I} = 1/2 * \left(\frac{sin^2(\theta_i - \theta_t)}{sin^2(\theta_i + \theta_t)} + \frac{tan^2(\theta_i - \theta_t)}{tan^2(\theta_i + \theta_t)}\right) \tag{1}$$

[4] Ueki, Noriko et.al, Eyespot-dependent determination of the phototatctic sign in Chlamydomonas reinhardtii, PNAS, vol.113, no 19, 5299-5304.

Models of photosynthesis-Continued

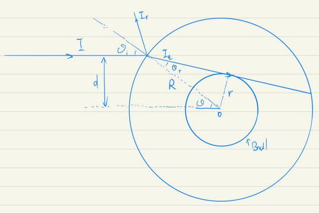

Figure: Spherical cell

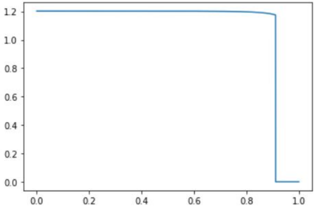

Figure: Result

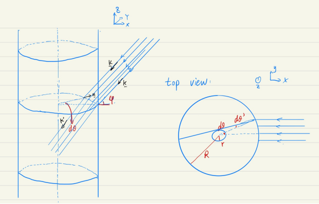

Figure: Infinitely long cylinder cell

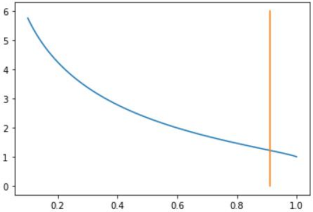

Figure: Result

Fluid dynamics: general principles

Microscopic level: fluid viscosity dominates. Ignore inertia
Equations for Stokes flow

$$\mu\nabla^2 u + \nabla p + f = 0 \tag{2}$$

$$\nabla \cdot u = 0 \tag{3}$$

Linearity: Grand resistance matrix Represent the force and Torque linearly with the rate of translation, rotation and extension.

$$\begin{aligned} F &= A(U - U_{flow}) + B^T(\Omega - \Omega_{flow}) - P \cdot E_{flow} \\ G &= B(U - U_{flow}) + D(\Omega - \Omega_{flow}) - Q \cdot E_{flow} \end{aligned} \tag{4}$$

5

[5] Throp, Ian R. and Lister, John, R. Motion of a non-axisymmetric particle in viscous shear flow. J. Fluid Mech. vol. 872, pp. 532-559

Fluid Dynamics: non-axisymmetric vs axisymmetric shape

- ellipsoidal under shear flow: periodic movement, follows the streamline [6]
- bent ellipsoidal under shear flow: not necessarily follows the streamline [7]

Question: Will this factor brings the advantage to escape vortex and travel faster in general stokes flow?
Model: Beads with fix joints (unfinished)

[6] Jeffery, G.B. The Motion of Ellipsoidal Particles Immerserd in a Viscous Fluid. Proc. R. Soc. Lond. A 102, 161-179

[7] Throp, Ian R. and Lister, John, R. Motion of a non-axisymmetric particle in viscous shear flow. J. Fluid Mech. vol. 872, pp. 532-559

Further work

For the photosynthesis model:
Calculate the light intensity for the case of p.lunula(bent ellipsoidal). May start from ellipsoidal and bent cylindrical cases.

For the study of fluid-dynamical behavior of p. lunula:
1. Use immersed boundary simulation or a two-way coupling system to solve the equations 4 for a general flow and see if the statistical behavior(e.g. distribution of displacement) would be different from axisymmetric case.
2. Solve the grand resistance matrix more precisely and compare the induced stresses.