Inner-asymmetry and Outer symmetry underlying life

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Abstract: Fusion of symmetry and asymmetry can be observed in biological molecules and cells. For example, the frequencies of purines and pyrimidines in double-strand DNA in a symmetric ratio of 1:1, while the asymmetric density ratios of purines and pyrimidines in RNA are between 1:1 and approximately 2:3.Size ratios of cells are also in the symbiotic fusion of symmetry and asymmetry. The cyto-fluid dynamic theory and onto-biology reported previously (Naitoh, 2001 & 2008) clarify the physics on the inevitability of symmetry and asymmetry underlying life. An important point is relatively inner cells among a colony divide into asymmetric ones, while outer cells on the colony surface proliferate symmetrically with an identical size. In this report, we examined the concept of inner-asymmetry and outer-symmetry by experiments.
Keywords: **Asymmetry, Cyto-fluid dynamics, Cell divisions, Nitrogenous base.**

I. INTRODUCTION

Nitrogenous bases which construct DNA and RNA are classified into purines and pyrimidines. The frequency and size ratio of purines and pyrimidines are around 2:3.

Then the symbiotic concept of symmetry and asymmetry is a key for understanding the spatial structures in living organisms. Naitoh has shown the model based on a continuum pheroid particle (parcel) to reveal the physics underlying the fusion of inner-asymmetry and outer-symmetry: the fact that inner cells divide into different size of cells, while outer ones differentiate with an identical size. [1, 2, 3]

In the reports [1, 2, 3], the equation describing cell deformation is obtained by assuming that flow inside the parcel is potential flow, while the state outside it is empty. The present study shows that the model equation is also valid for the opposite situation: the liquid flow outside the parcel and nothing inside the parcel and also that the inner-asymmetry and outer-symmetry also occur for the situation of inner empty.

Then, we examined the concept of inner-asymmetry and outer-symmetry further by experimental observations of division processes of yeast (Saccharomyces cerevisiae).

II. CYTO-FLUID DYNAMICS THEORY

1. Assumption

A.Original Model [1, 2, 3]

Here,we will consider two nitrogenous base, such as the pair of a purine and a pyrimidine, connected by hydrogenbonds in a large quantity of water. Owing to
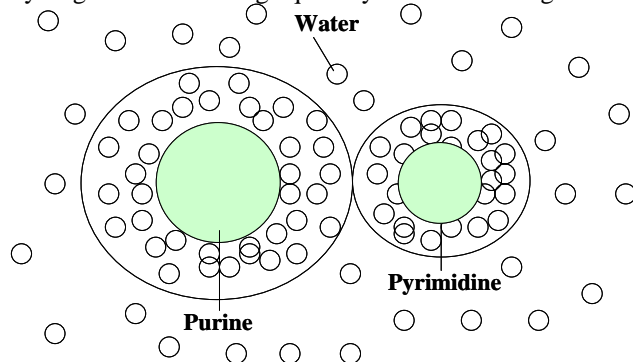

Fig.1. Hydrogen-bonded connection of purine and pyrimidine surrounded by water molecules

the influence of the nitrogenous bases, water molecules around the bases have different densities and arrays from those far away. Thus, we divide the water into two regions by drawing a boundary around bases. We assume that each nitrogenous base and the water molecules inside the boundary act as a flexible continuum spheroid particle (parcel), in which the flow is irrotational (Fig.1) Further, we assume that the spheroid particle size is proportional to the size of each nitrogenous base.

The internal flow is incompressible and irrotational flow. Then, the velocity potential ϕ for the internal flow is [3]

$$\Delta\phi = \frac{\partial^2 \phi}{\partial x^2} + \frac{\partial^2 \phi}{\partial r^2} = 0 \tag{1}$$

where x, r denote the cylindrical coordinates.

Then, it satisfies the condition

$$0 \le (x - X_s + a)^2 / a^2 + r^2 / b^2 \le 1$$
$$X_s - 2a \le x \le X_s, 0 \le |r| \le b \tag{2}$$

where X_s denote the surface position related to the absolute origin [3]. Variables a and b denote the radii in the single spheroid parcel. This equation represents inside of the parcel.

The assumptions of potential flow and spheroid droplet necessarily lead to Eq. 3 on the velocity v

$$v_x \equiv \partial \phi / \partial x = A(x - X_s + a) + d(X_s - a) / dt$$
$$v_r \equiv \partial \phi / \partial r = -Ar / 2 \tag{3}$$

where A is a function of time t. [3, 4] The terms of $A(x - X_s + a)$ and $-Ar/2$ representing the velocities observed at the center of gravity. The term of $d(X_s - a)/dt$ evaluate the translation motion of the parcel center of gravity. [3]

By using Eqs. (2) and (3), we show two-dimensional velocity distribution in a flexible spheroid. (Fig.2)

B. A New Model

In the cyto-fluid dynamic theory Naitoh, [1,2,3] the flow outside the flexible continuum particle is a vacuum. Here, we will derive the governing equation ofr the opposite state: inner empty. (Fig.3).

The external flow is also incompressible and irrotational flow. Then, the velocity potential ϕ' for the external is

$$\Delta \phi' = \frac{\partial^2 \phi'}{\partial X^2} + \frac{\partial^2 \phi'}{\partial R^2} = 0 \tag{4}$$

where X, R denote the cylindrical coordinates.

Then, X, R can be represented by using x, r (original coordinates). (See Eqs. 5 and 6.)

$$X = \frac{a^2}{x - X_s + a} \cos^2 \left(\arctan \left(\frac{r}{x - X_s + a} \cdot \frac{a}{b} \right) \right) \tag{5}$$
$$+ X_s - a$$

$$R = \frac{b^2}{r} \sin^2 \left(\arctan \left(\frac{r}{x - X_s + a} \cdot \frac{a}{b} \right) \right) \tag{6}$$

Then, the flow outside the spheroid parcel satisfies the condition of Eq. 7.

$$1 \le (X - X_s + a)^2 / a^2 + R^2 / b^2 \le \infty$$
$$0 \le |X| \le \infty, 0 \le |R| \le \infty \tag{7}$$

The assumption of potential flow outside the parcel

necessarily leads to Eq. 8 for the velocities v.

$$v_X \equiv \partial \phi / \partial X = A(X - X_s + a) + d(X_s - a) / dt$$
$$v_R \equiv \partial \phi / \partial R = -AR / 2 \tag{8}$$

Equations (7) and (8) show the two-dimensional flow velocity distribution in Fig.4.

Equations 4 and 8 imply that the governing equation is also applicable for all the cases where inner density differs from that of outer area, even if both inner and outer regions are not empty.
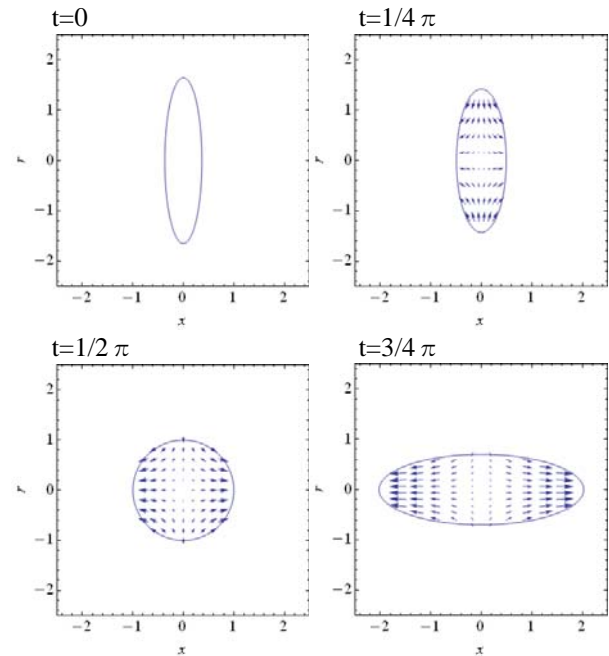

Fig.2. Velocity distribution of the parcel inside (Flow velocity satisfies the following conditions.
($A = \sin t$, $a = e^{-\cos t}$, $b = e^{-\sin t/2}$, $X_s = a$)
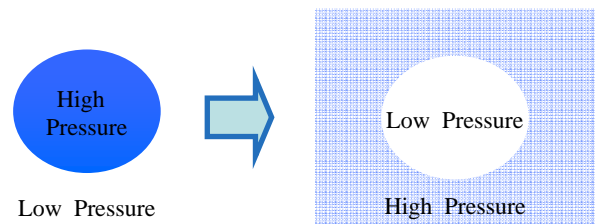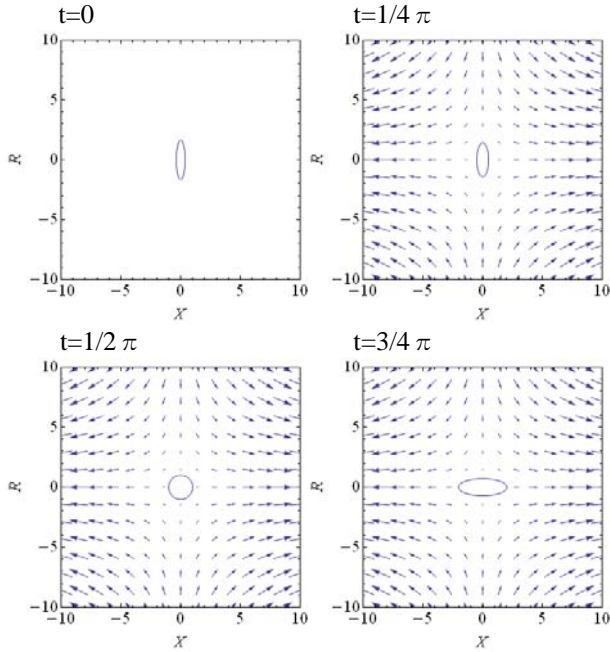

Fig. 3. The condition changed in the model

Fig.4. Velocity distribution of the parcel outside.
$(A = \sin t , a = e^{-\cos t} , b = e^{-\sin t/2} , X_s = a)$

2. Size of Parcel

Based on these assumptions in Section II.1, we derive the common deterministic momentum equation describing particle deformation. [1,2,3] When a small disturbance is given for two connected flexible particles, the dimensionless deformation ζ of each particle, dependent on dimensioless time τ, can be described as

$$d^2\zeta/d^2\tau = (e-1)(d\zeta/d\tau)^2 + (e^3-3)\zeta + q(\tau) \qquad (9)$$

where parameter e and term $q(\tau)$ denote the size ratio of the two particles connected at the equilibrium condition and the time-dependent force generated by the other connected particle, respectively. Equation 9 can be applied for all the cases where density varies between inner and outer regions, when we want to know the quasi-stable ratio of e.

When the particles are spheres at the equilibrium condition, ζ is zero. A symmetric ratio of 1.0 makes the first term on the right-hand side of the equation zero, while an asymmetric ratio of $\sqrt[3]{3}$ around 1.5 makes the second term zero. The deformation speed is smaller for $e=1.0$ and $\sqrt[3]{3}$ than for the other values of e.

Life is relatively quasi-stable when the size ratio of hydrogen-bonded nitrogenous bases takes the values of 1.0 and $\sqrt[3]{3}$ around 1.5.

The present quasi-stability maintains the hydrogen-bonded pairs of two identical bases and of purine-pyrimidine pairs over a period of time at the initial stage just after the small disturbance affects the pairs. (Pairs of two identical bases can often be seen in RNA, while purine-pyrimidine pairs are numerous in RNA and DNA.)

It is stressed that the flow inside the flexible continuum particle is potential flow, i.e., irrotaional flow, because impulsive disturbances generate potential flow at the start of deformation motions. (It is well known that an impulsive start produces irrotational flow, which also satisfies the Navier-Stokes equations.) [1,2,3]

III. SPATIAL STRUCTURE OF CELL [1]

The cyto-fluid dynamic theory [1,2 3] also clarifies the relation between small deformation and asymmetric division for the aggregation of cells such as those in a colony, because a cell is also a flexible continuum spheroid particle.

Let us separate cell aggregation into two parts, the internal side around the center of the aggregation and the external side close to the surface. External cells close to the surface move relatively easily under the influence of inhomogeneous force, because one part of the cell is free without any connection to other cells. However, internal cells often receive homogenous forces from many directions due to the presence of other cells, making it relatively difficult for them to move relative to the origin on the earth. Thus, inner cells deform relatively easily. (Fig.5) As a result, the inner and outer cells determine whether cell divisions are asymmetric or symmetric, respectively. [1,2]
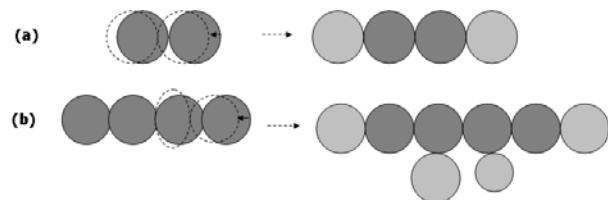

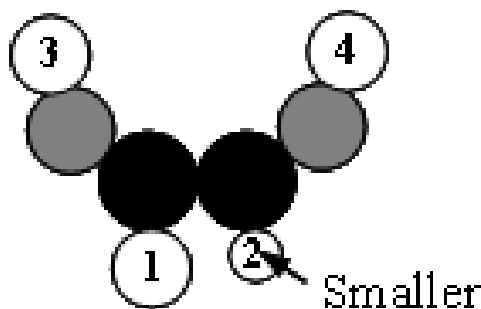Fig. 5. Division pattern related to neighboring states of cells.

Fig. 6. Cell division process of
Saccharomyces cerevisiae.

Fig.7. Relation between the size ratios
between inner cell 1/2 and outer cell 3/4

Let us examine the cell division process of yeast (Saccharomyces cerevisiae), because symmetric and asymmetric size ratios are also observed at the cell level of microorganisms. We cultivated Saccharomyces cerevisiae at a constant temperature of 37 degrees Celsius on a warm plate and observed continuously under a microscope until eight cells were formed. Figure 6 shows that internal mother cells (black) generate child cells in asymmetric division, while external mother cells (gray) produce symmetric ones. Figure 7 shows the relation of the size ratio of inner cells (1/2) and that of outer ones (3/4). Inner cells divide into more asymmetric size ratios, while most of outer cells are close to symmetric ones.

IV. CONCLUSION

The cyto-fluid dynamic theory is extended for a wide range of density variations between inner and outer regions of parcels.

Asymmetric and symmetric size ratios are also observed at the cell level of microorganisms. For example, internal mother cells generate child cells in asymmetric division, while external mother cells produce relatively symmetric ones in Saccharomyces cerevisiae.
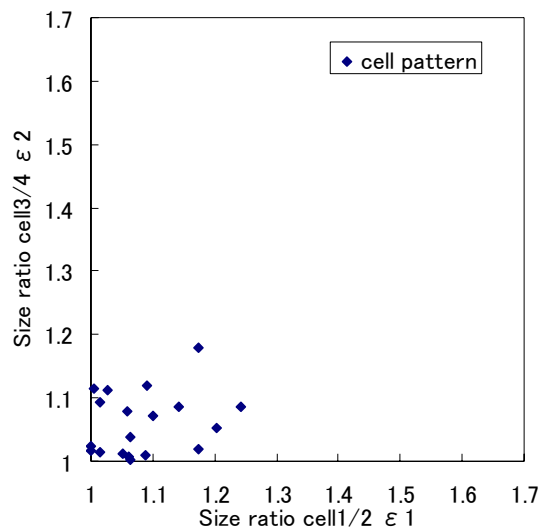
REFERENCES

[1] Naitoh K, (2009) Physics underling Topobiology: Space-time Structure underlying the Morphogenetic Process, IFMBE Proceedings Vol.23.
[2] Naitoh K, (2008) Stochastic determinism underlying life: systematic theory for assisiting the sythesis of artificial cells and new medicines, Artif Life Robots (2008) 13:10-17
[3] Naitoh K, (2001) Cyto-fluid Dynamic Theory, the JAPAN JOURNAL OF INDUSTRIAL AND APPLIED MATHEMATICS Vol.18. No.1, pp. 75-105.
[4] Brazier-Smith, P.R., (1971) The stability of a water drop oscillating with finite amplitude in an electoric field, J. of Fluid Mechanics, Vol.50, part3.
[5] Kataoka K and Ioi T, (1993) Fundamental of Mechanical Vibration, CORONA PUBLISHING (in Japanese)