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Morphogenic fluid-dynamics:

Similarity between engine flow and brain shape

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“I could do the CFD on turbulence and combustion in engines under the direction of Prof. Kuwahara. Now, the engine research leads to a new research area for the next generation.”

Abstract

Molecular and cellular biology research has resulted in a huge bio-dictionary of molecules including nucleic acids, proteins, and lipids. This has given rise to a new mystery, i.e., the self-organizing principle based on the spatiotemporal network of the molecules. Let us examine the mystery by classifying it in terms of space and time.

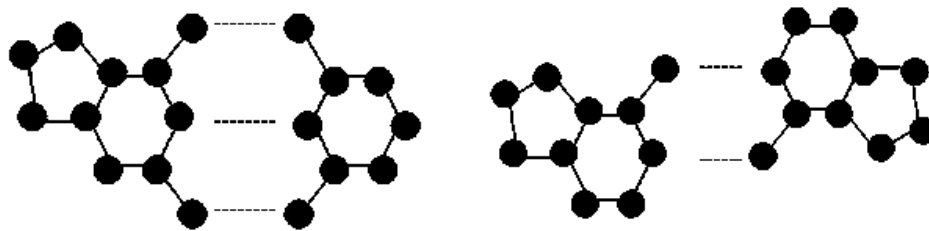
The main spatial mystery is the bipolar order of symmetry: asymmetric Watson-Crick base-pairs in DNA and symmetric ones in RNA, asymmetric and symmetric divisions of microorganisms and stem cells, and left-right asymmetric liver and symmetric kidneys. (Fig. 1)

As water is the chief component of life, modern fluid-dynamics based on the stochastic determinism reveals the spatial mystery in fractal nature. The cyto-fluid dynamic theory for describing the deformation and motions of flexible parcels such as connected cells and connected nitrogenous bases [1-7] is used to examine the relation between the type of motion and parcel size. The dimensionless deformation rate x of each parcel dependent on dimensionless time t can be described as

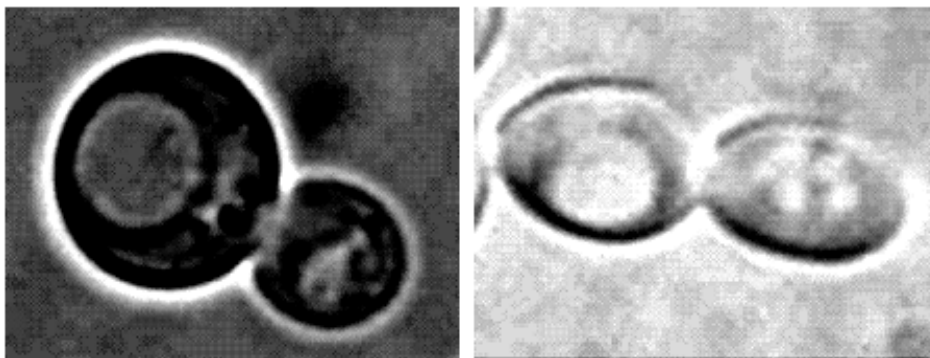
$$d^2x/dt^2=(e-1)(dx/dt)^2+(e^3-3)x+q(t)+\varepsilon_x \quad (1)$$

where the parameter e , the term $q(t)$, and the term ε_x denote the size ratio of the two parcels connected under equilibrium conditions, the time-dependent force generated by the other connected particles, and random force, respectively. When the particles are spheres under equilibrium conditions, x is zero. A symmetric ratio of 1.0 ($e = 1$) makes

the first term on the right-hand side of the equation zero, while an asymmetric ratio of $\sqrt[3]{3}$ around 1.5 ($e^3 = 3$) makes the second term zero. Life is relatively quasi-stable because d^2x/dt^2 becomes relatively smaller, when the size ratio of parcels connected takes these values of $e = 1$ or $e^3 = 3$. The first and second terms also show that symmetric ($e = 1$) and asymmetric ($e^3 = 3$) parcel divisions are more stable for the small disturbance of motion (dx/dt) and parcel deformation x , respectively. (Quasi-stability weaker than the neutral stability is that one of the convection and tension terms in the right hand side of Eq. 1 becomes zero.)



(a)



(b)

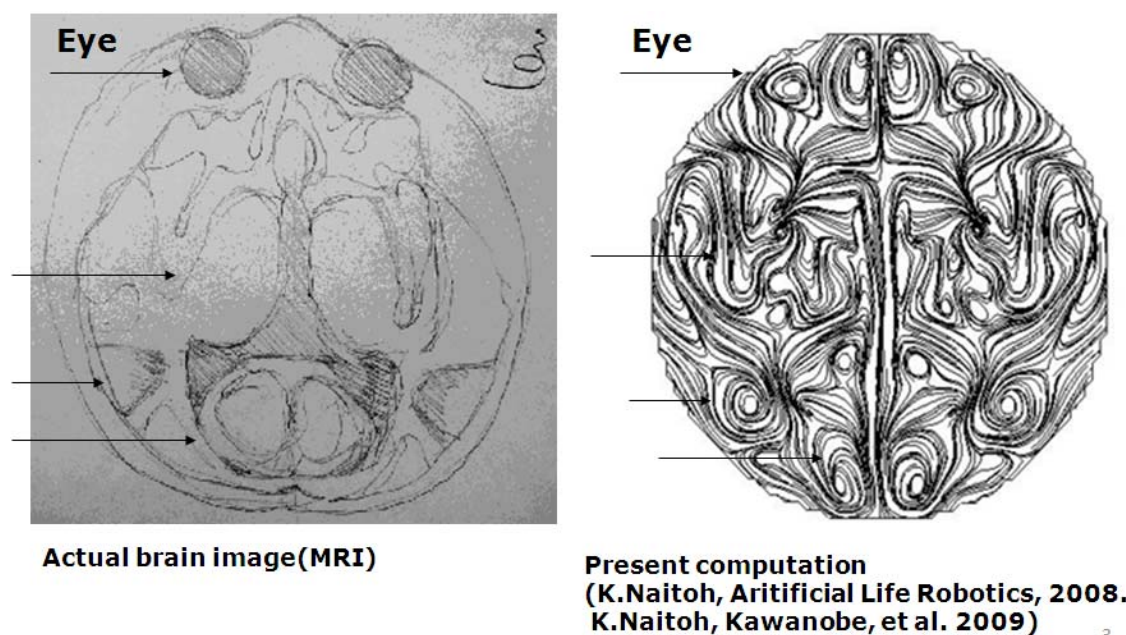


(c)

Fig. 1 Bipolar order. (a) Asymmetric Watson-Crick base-pairs in DNA and symmetric ones in RNA. (b) Asymmetric and symmetric divisions of Yeast cells. (c) Left-right asymmetric liver and symmetric kidneys. (K. Naitoh, Japan Journal of Industrial and Applied Mathematics, 2001, K. Naitoh, Artificial Life and Robotics, Springer, 2008, K. Naitoh, Proceedings of ICBME2008, Springer-Verlag, 2008.) [1-9]

Equation 1 also reveals the reason why early embryo without inner cells proliferates symmetrically, because the first term in the right hand side of Eq. 1 implies the symmetry of 1:1 is relatively stable (quasi-stable) for velocity disturbances entering into outer and open cells and also because outer cells open to the external area are not deformed very much. Asymmetric ratio of $1:\sqrt[3]{3}$ for inner cells is quasi-stable for the deformation disturbance of γ , because inner cells closed by the other cells are deformed easily. [8, 9] Liver is asymmetric because blood is closed to the outer world and deformable, while kidneys open to the mother body are symmetric because of continuous urine, which leads to less deformation. [8, 9]

Moreover, computational fluid dynamics code used on supercomputers can reconstruct in detail the three-dimensional structures of systems such as embryo and brain. (Fig. 2) [10] This morphogenic dynamics will bring new technologies related to regenerative medicine and morphogenic control. Then, stochastic determinism, a new method between the Boltzmann equation and the Langevin equation for solving the mesoscopic phenomena, makes the T-S wave simulation possible, as a base for predicting the transition to turbulence in diseased blood vessels. (Fig. 3) [11]



(a)

(b)

Fig. 2 Concavity and convexity in brain. (a) MRI image having eyes. (b) Computational result. (K.Naitoh, Artificial Life and Robotics, Springer, 2008.) [10]

The main temporal mystery is the basic molecular instrument regulating the biological rhythm common to the cell cycle, stem cell cycle, circadian clock, and so on. Thermo-dynamics solves this mystery. This common rhythm tinkled by the minimum hyper-cycle of only six molecular groups is also induced with the bipolar order of symmetry and asymmetry. [8]

An important bio-grammar is that, after natural thermo-fluid dynamic forces induce the specific structures of molecules, molecular networks, cells, and organs, DNA fixes the structures.

This approach based on thermo-fluid dynamics also reveal that long introns and junk acquired during the evolution have several functions including activation of macroevolution. [12, 13] Then, we clarify the reason why only five nitrogenous bases for nucleic acids and twenty amino-acids for proteins are naturally selected during evolution. [7, 9] This will be important, because further knowledge of evolution leads to a better understanding of the self-organizing processes in individual organisms. Natural data during the past 4,000-million-year history validate the evidence of the bio-grammar clarified by thermo-fluid dynamics.



Fig. 3 Computation of the transition point in space, which is done by the stochastic determinism approach. [11] (K. Naitoh et al. Computational Fluid Dynamics 2008, Proceedings of 5th International Conference on Computational Fluid Dynamics, Springer-Verlag)

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