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Theoretical research to extract, combine and generate concepts for understanding life phenomena

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Living systems evolve through interactions with the environment, which are nonequilibrium processes that resist the law of increasing entropy in the environment and maintain their organization by exhausting an entropy inflow from the environment. Although several principles have been proposed to explain the nonequilibrium processes of living systems and the mechanism of entropy extraction, a unified principle has not yet been elucidated. In this study, different concepts in mathematics, physics, system biology are combined to understand and abstract dynamics of biological phenomena. Therefore, in chapter 1, topological geometry and continuum mechanics are used to explain the dynamics of such life phenomena and environmental changes.　In chapter 2, Some models describing dynamics of some structures, elements and flows are indicated to explain the mechanism of entropy pumping in living systems. In chapter 3, some charts are used to analyze dynamics of entropy in biological phenomena. In addition, the dynamics between probability and state are considered. Then, some factors are discussed to analyze the mechanisms that support the recursiveness and stability of life phenomena. Furthermore, existing principles are implemented to describe the micro- and macro-mechanisms and dynamics that support the space-time stability and evolution of living systems. Finally, through by these considerations and analyses, we present a general descriptive model to explain of the life phenomenon as a system. Moreover, it is considered and analyzed for which the dynamics and functionality of fractal structures and related principles relevant to chaotic behavior at many scales.

Key words: Living system, topology, stochastic process, continuum, entropy

1.1 Background and Objectives

On the bilobed structure-encompassing torus structure similarity of life phenomenon dynamics as a stochastic process

Dynamic non-equilibrium interactions are classified as follows (1) interactions that involve a change toward some equilibrium or "local" low energy metastable state, (2) interactions caused by a response to an external stimulus (force or energy injection), or (3) interactions in which a continuous (3) interactions that always remain in a "steady state" configuration due to continuous energy injection. A fourth dynamical interaction is an apparent, but not equilibrium, "fluctuation" caused by thermal randomness around the equilibrium configuration [Israelachvili, 2013].

Living systems move away from unpleasantness and approach pleasantness. The living system selects, acquires, combines, and organizes its own adaptive spatiotemporal paths from the past and future as a probability space.

Dissipative and conservative systems are important concepts that distinguish dynamical systems. Originally, a system in which the sum of potential energy and kinetic energy is kept constant (i.e., the conservation law of energy holds) is called a conservative system, and a system in which it does not is called a dissipative system. Dissipative systems include both systems in which the total sum of energy increases owing to an inflow of energy from outside and systems in which the total sum decreases owing to an outflow of energy [Serizawa, 2015].

However, the terms conserved and dissipative systems are often used in a more extended sense, according to which a system in which the volume of a small portion of phase space does not change is called a conserved system and a system in which it changes is called a dissipative system [Serizawa, 2015].

A stable limit figure that attracts orbits is called an attractor. Attractors include fixed points in dimension 0, limit cycles in dimension 1, as well as tori in dimension 2, and chaotic shapes whose dimension is a fraction between 2 and 3 [Serizawa, 2015].

There are three fundamental laws or principles that control entropy production in physical systems [Serizawa, 2015].

They are the second law of thermodynamics, the principle of Minimun Entropy Production (mEP), and the principle of Maximum Entropy Production (MEP) [Serizawa, 2015].
In nature, chaos with multiple degrees of freedom, such as multiple positive Lyapunov numbers, is likely to be much more common. For spatially and temporally turbulent phenomena, it is necessary to use partial differential equations instead of ordinary differential equations [Takayasu, 2020].

The following delay differential equation representing feedback is often used to study chaos with multiple degrees of freedom [Takayasu, 2020]:

$$\dot{x}(t) = -\gamma x(t) + f(x(t - t_R))$$

Equations describing physical phenomena in dynamical systems are often described using differential equations. In general, if the variables are $\vec{x} = (x_1,\cdots,x_n)$, the equation is as follows [Takayasu, 2020].

$$\frac{d\vec{x}(t)}{dt} = \vec{F}(\vec{x}), \quad \vec{x} \in R^n$$

The vector field generally varies with μ. If the topology of the flow in phase space changes when the parameter is changed, this phenomenon is called bifurcation [Takayasu, 2020].

Saddle node bifurcations and hop bifurcations are typical examples of bifurcation phenomena. A saddle node bifurcation is a bifurcation in which the eigenvalue of the mapping becomes unstable at +1 when the parameter is changed, and the saddle and node collide and disappear. A bifurcation caused by destabilization of the real part of a complex eigenvalue is called a hop bifurcation [Takayasu, 2020].

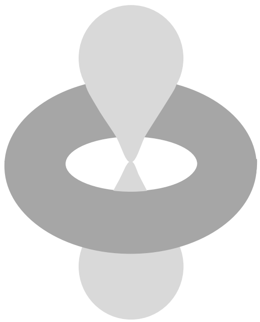
The edges of chaos described by the mutual information content exist only in a very narrow region of order parameters, the factors that define randomness [Uragami, 2021].

Assuming a system of fluid that is heated on one side and cooled on the other, as the temperature gradient increases, the liquid begins a macroscopically ordered rolling motion, forming a macroscopic pattern. The temperature gradient is called the control parameter in synergetics and dynamics, and is the ordered variable that governs the macroscopic behavior of the system [O'Neill, 1995].

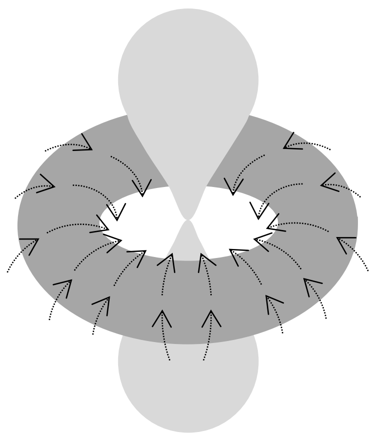
Method

It is considered the recursiveness and dynamism of life phenomena and the nature of pursuing of specific directions, gradients, and properties in the temporal direction will be considered. In addition, it is also considered the vector fields of flows and their temporal dynamism in phases of support and selection pressure in the environment. Then, it is generalized a model that describes these space-time dynamisms, relationships, and interactions by combining concepts from topological geometry and fluid dynamics.

The asymmetric separation of materials due to physicochemical phase boundaries and selection pressure adaptively evolves the system being selected, increasing the inertia of the asymmetric process of evolution.

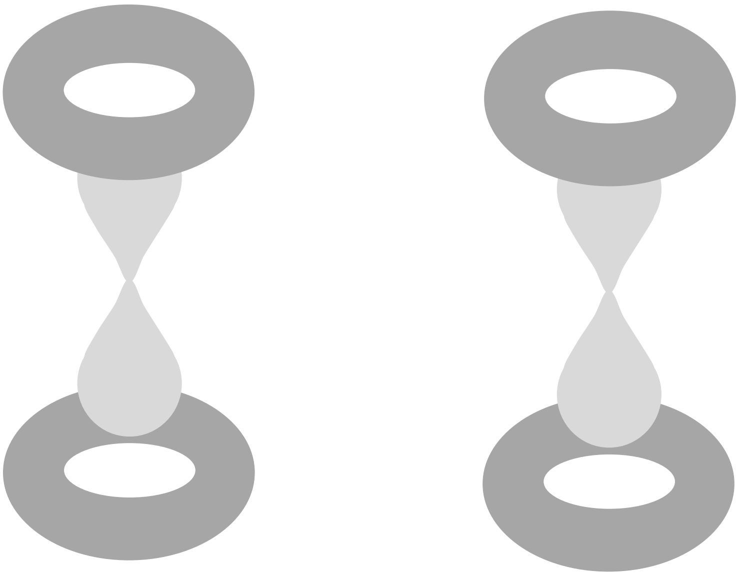


The bilobed and torus structures, which show the relationship between the living system and the environment, contain vector fields that indicate the phase flow.



The vector field of the torus structure decreases the entropy, and the bilobed structure, by coevolving with the torus structure, increases the resistance to increases in the entropy of the environment.

Living systems remain, persist, and evolve by organizing them while being organized by support from the environment and selection pressure.



The equilibrium system is located in the center of the 1-leaf hyperbolic plane of the probability space of the time-space distribution, which converges and diffuses the elements of the living system.

(The study in this paper is based on theoretical considerations, additional experiments are needed to establish evidence.)

2.1 Background and Objectives

In prokaryotic cells such as bacteria, it is difficult to detect the direction of concentration gradient by the number of ligands on the cell membrane surface due to their small size. The frequency of tumbles decreases if the ligand concentration is higher than before, whereas it increases if the ligand concentration is lower, indicating chemotaxis in the direction of higher ligand concentration [Hatakeyama, 2023].

Similarities between curved spacetime and fluid fluctuations are observed for inviscid fluids in the field of quantum hydrodynamics [Tsubota, 2018].

A dissipative system with periodic external forces can be expressed as follows, with the fluctuation force as ξ .

$$\frac{\partial x}{\partial t} = -\frac{\partial V(x,t)}{\partial x} + \xi$$

The time evolution of the potential of such a system is given by the normalization condition

$$n_+ + n_- = 1$$

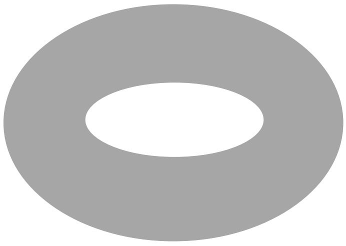
It can be expressed as

$$\frac{dn_\pm}{dt} = -W_\mp(t)n_\pm + W_\pm(t)n_\mp$$

Method

Vector fields in systems and stochastic spaces and the temporal dynamism of elements and their evolution as systems are described and their stability, functionality, and entropy pumping out of the system are analyzed.

The channel structure, hydrothermal vents, topology of the earth and the flow vector field of the surrounding phases are analogous.



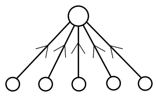
A three-dimensional representation of the trajectory of elements orbiting the torus structure in the direction of the time axis is a helical structure.

The elements orbiting the torus structure can be regarded as dissipative systems with periodic external forces.

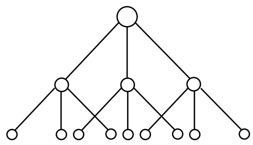
The cycle of electron donor acquisition and exothermic reaction by catabolism may have functioned as a mechanism for primitive life to maintain homeostasis in the system in response to changes in the warm and cold environments in the phase flow cycle at hydrothermal vents.

The exchange of ions through ion channels may also serve as a mechanism for regulating the specific gravity and controlling movement in the system.

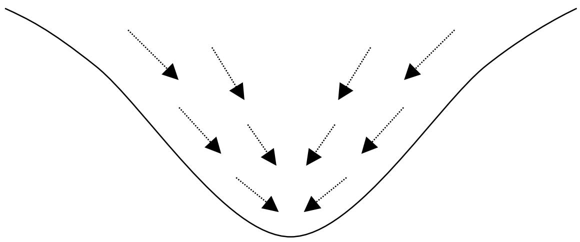
The formation of a superstructure in a tissue can be thought of as a phase rectification and vector synthesis process.

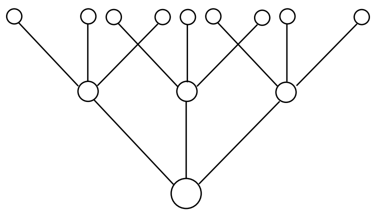


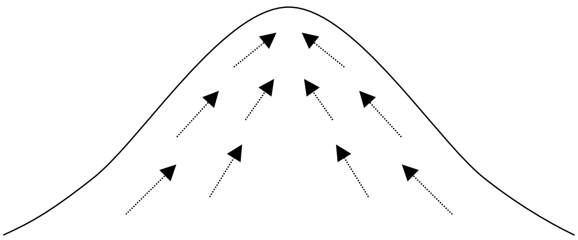
On the other hand, the ends of the organizational structure are thought to be responsible for pumping out entropy.

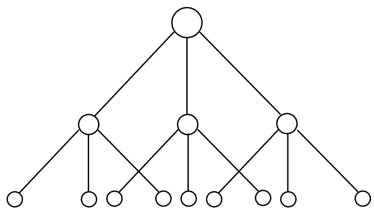


The gradient of the probability density constitutes a vector of phases and organizes the elements.









3.1 Background and Objectives

Concentric waves expanding outward are observed in the Belousov-Zhabotinsky reaction. In an oscillating system, when the frequency is higher than that of the surroundings due to impurities, concentric waves are generated around the center of the system. In reaction-diffusion systems with oscillatory characteristics, concentric waves can be created by placing a pacemaker [Ohta, 2008].

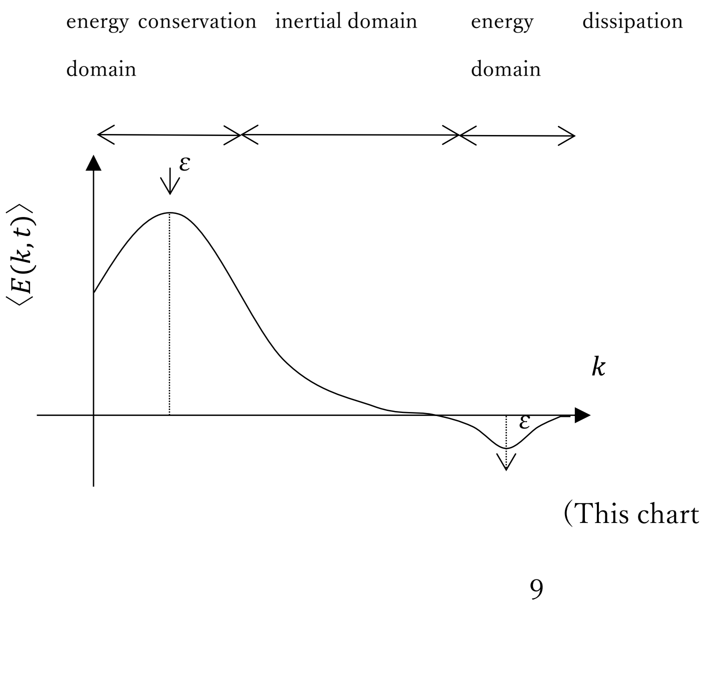
When a small torque is applied to a beam of elastic material, a linear relationship exists between the torque and the strain due to torsion, and energy is stored in the DNA due to torsional deformation [Rob Phillips, 2011].

In developed steady-state turbulence, one of the physical quantities that gives universal and important statistical properties is the energy spectrum $E(k,t)$. The energy spectrum is defined in the small region of k as

$$\langle E(k,t) \rangle = C\varepsilon^{2/3} k^{-5/3}$$

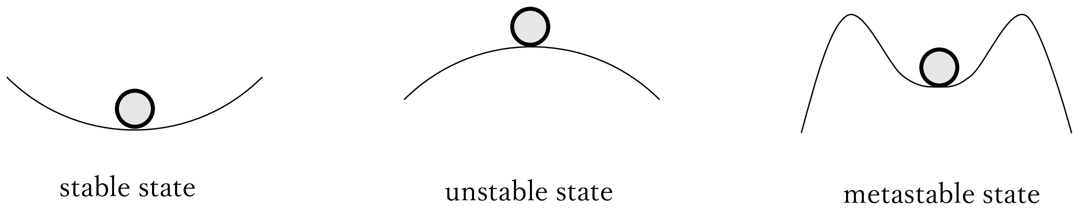
in the small k region. Such an obedience to the equation is called the Kolmogorov law.

For a scale l of steady turbulence, there is a sufficiently large scale separation between l_0 and l_k to satisfy$l_0 \gg l_k$. If $k \sim k_0$ is called the energy conservation region, $k_0 \ll k \ll k_K$ is called the inertial region, and $k \sim k_K$ is called the energy dissipation region, the conceptual diagram of the energy The conceptual diagram of the energy spectrum in a developed uniform steady turbulence is as follows [Tsubota, 2018].



(This chart was cited from [Tsubota, 2018].)

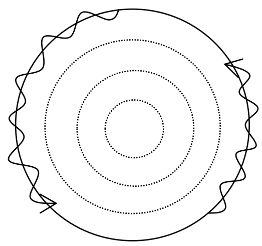
The following conceptual diagram can be used to intuitively understand the stability and instability of an object [Tsubota, 2018].



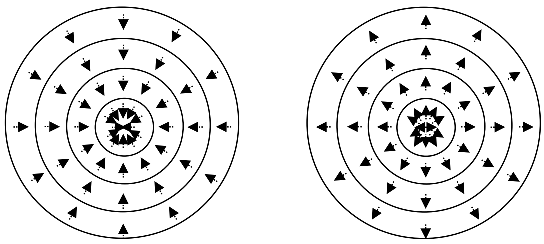
Method

Several geometric and physical models related to the absorption and pumping out of entropy in life phenomena are described. Then, mechanisms and forms that support system stability, dynamics and function are described. Finally, conceptual models will be presented that describe the temporal and spatial dynamism and continuity of life phenomena.

Spherical structures produce sparse and dense waves that equalize the entropy from the environment along the surface, converge concentrically inward, and diffuse outward.

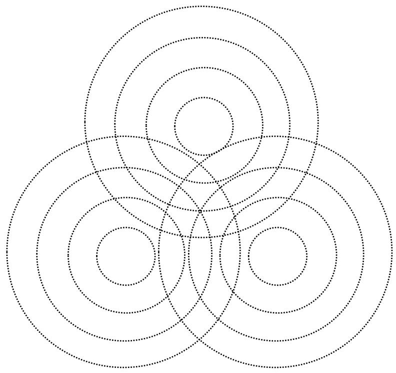


The process of phase flow toward the center of the sphere and diffusion out of the center again decreases entropy.



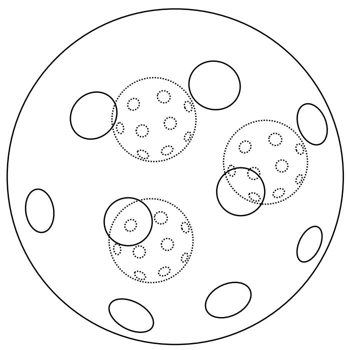
The phase shift of the two-dimensional vector space of three-dimensional plots in the mountain climbing method may be a model that can be used to describe the homeostasis of a living system.

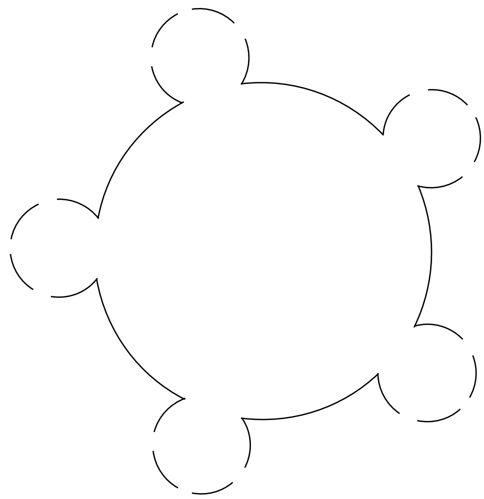
The support and selection of living systems by their environment can be described as a process of rectification or organization of the phase flow.
The trajectories of the intersections of concentric ripples of different sparse and dense waves take the shape of a Bethe lattice.



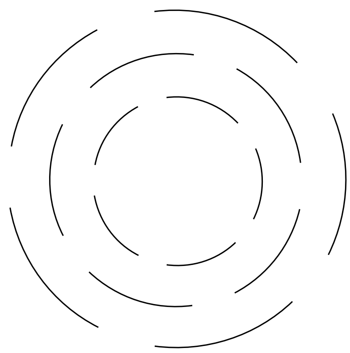
The recurrent repetition of divergent and convergent processes in life phenomena can be compared to the repetition of the conversion between centrifugal and centripetal forces in a hollow celestial body.

The probability space of a multi-hole torus nested structure is analogous to that of a three-dimensional fractal concave spherical closed space.





Individuals surrounded by entropy-extracting systems combine to increase their ability to extract entropy.



When asymmetric materials are connected and self-revert, they become orbiting systems with both positive and negative signs.

Filtration, crystallization, and selective adsorption decrease entropy over time.

The entropy and systems that absorb and exhaust entropy may co-evolve.

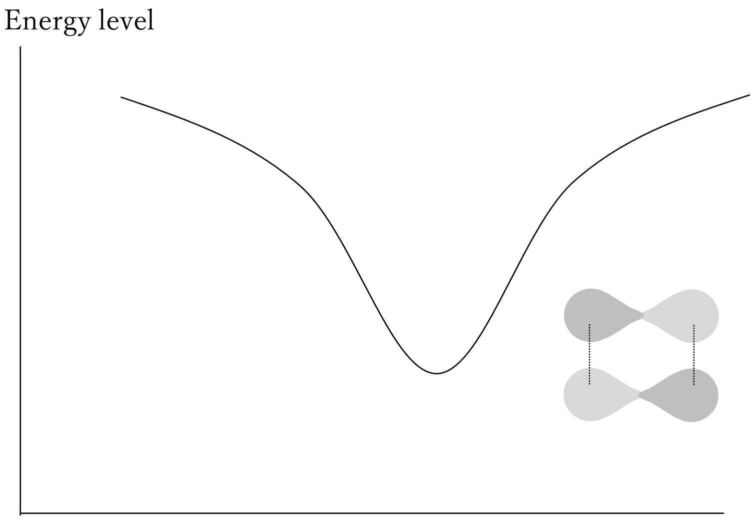
The separation and binding of RNA molecules and their dynamics as a chain structure absorb and exhaust the entropy.

Positively charged RNA chains aggregate in the center of the vesicle, which is positively charged on the outside and negatively charged on the inside, and collect energy that is collected in the center, and perform motion.

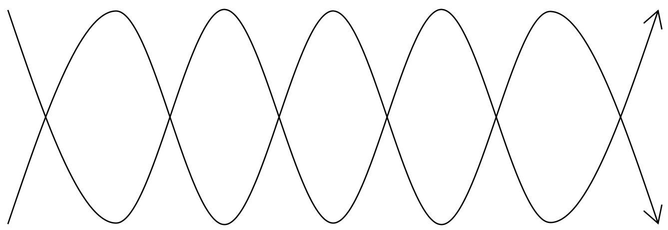
RNA molecules, which are connected in chains and engage in dynamic physical interactions in the stranded and aggregated states, may have absorbed and expelled entropy and supported the pumping out of entropy in living systems.

The separation and binding of RNA molecules and their dynamics as chain-like structures absorb and exhaust the entropy.

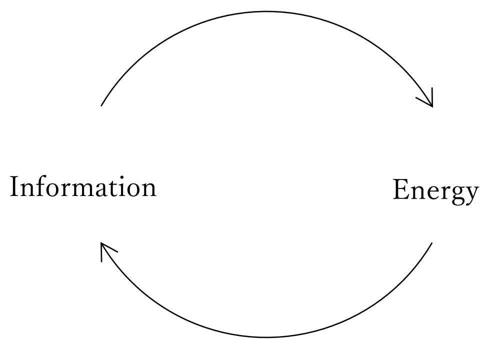
Coupling of the system with complementary pairs increases the resistance to entropy.



In addition to complementarity and progression, DNA chains exhibit differences in fitness through the formation of base pairs, embodying mutual support and selection among systems, which is a universal mechanism as a life phenomenon. In addition to complementarity and progression in polarization, the DNA strand shows differences in fitness through the formation of base pairs, and embodies mutual support and selection among systems, which is a universal mechanism as a life phenomenon.

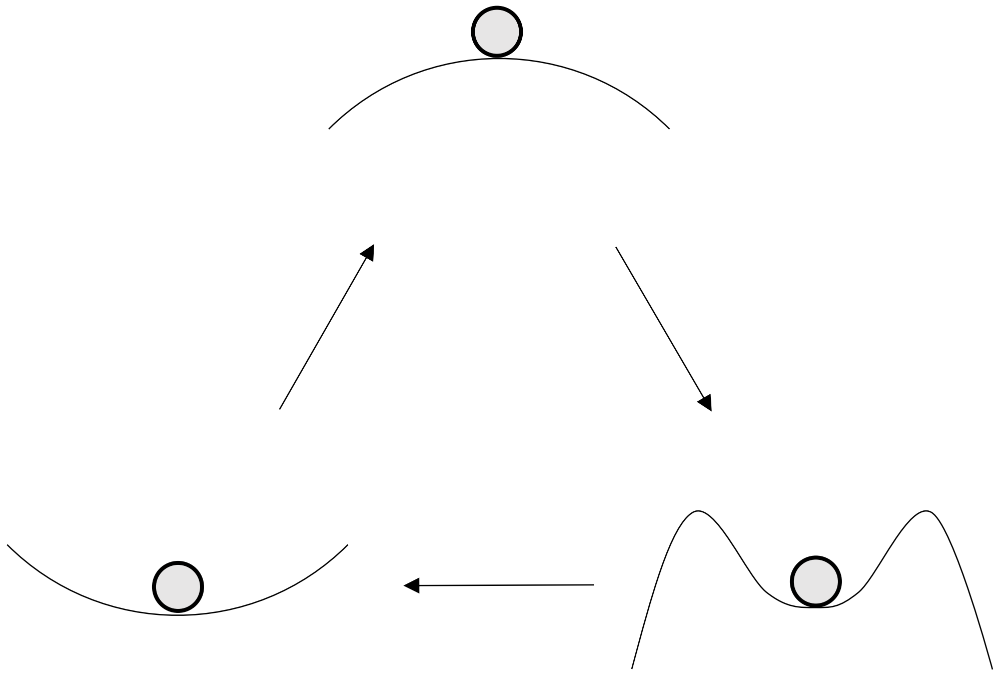


Generalizations can be made about the cycle in which information organizes energy and energy supports the processing of information in biological phenomena.

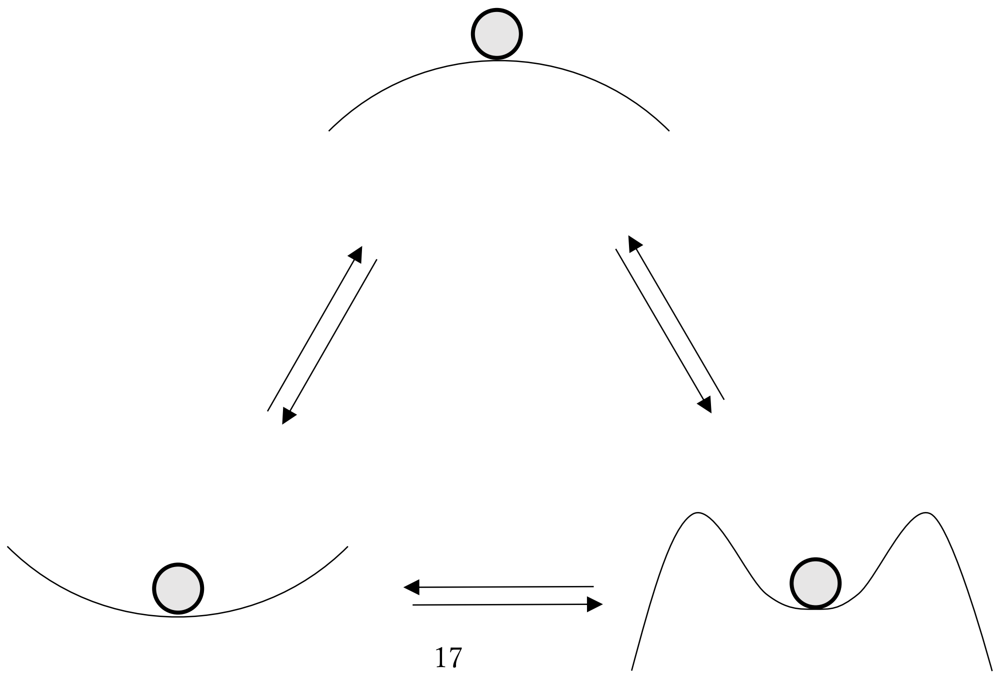


Based on a conceptual diagram of quantum hydrodynamic flow stability, it might be generalized that life analyzes, selects, and harmonizes internal and external cycles by organizing the dynamical equilibrium of living systems, selecting adaptive space-time paths.

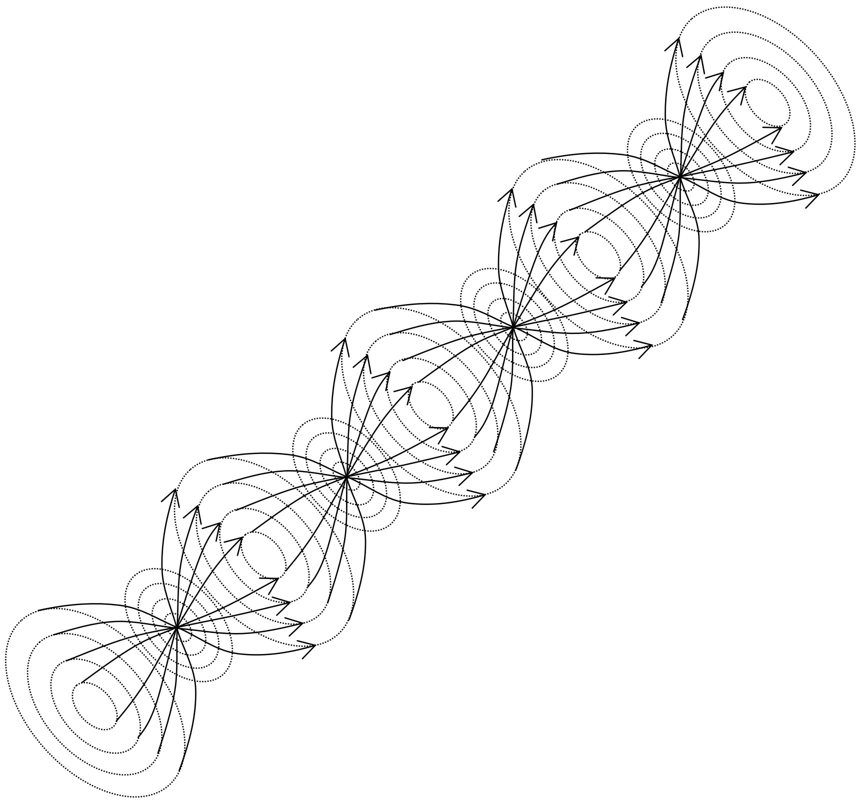
Biological system



External environment



In three dimensions, life phenomena are systems that continuously connect, transform, and harmonize organizations through repeated diffusion and convergence of vector fields in the time axis direction, co-evolving with the probability space in the environment and enhancing the ability to pump entropy out of the environment.



(The study in this paper is based on theoretical considerations, additional experiments are needed to establish evidence.)

Discussion

Do dynamic systems, in which phases in the system cycle, changes in form accumulate and co-evolve with the environment, increase their resistance to increasing entropy? Fractal structures are formed over time, which reduces entropy. We can say that electrons (the mass is quite limited.), heat, information, energy, and time, which have no mass, form flows and are related to life phenomena, are organized by separation and combination in life phenomena, have absoluteness and relativity, topology and flows govern life phenomena, and are related to entropy. The speed of electron movement is high, and time cannot be stopped. Order is created when the flow of phases occurs between the heat source and the cold source, and when it is a circulatory system that circulates around and returns to itself. As time progresses, the living system can deepen its phylogenetic tree, the morphology of the living system, the distribution of individuals in the population, and the fractal structure of the population distribution in the environment, thereby resisting the increasing entropy of the environment. The Earth, hydrothermal vents, and living systems are similar to a torus structure in which the flow of surrounding phases is self-reverting, and they are also similar in that they have cyclic cycles of reduction and oxidation reactive systems.

What are the roles of the individual and cooperative functions of reduction reactions as anabolic reactions and oxidation reactions as catabolic reactions in these systems? In particular, what is the relationship between the thermodynamic dynamics and entropy of reduction and oxidation reactions as chemical reaction processes? What do reduction and oxidation reactions support and what do they eliminate in these systems?

A very brief generalization of living systems would be a dynamic system in which dynamic matter, in a flow of circulating, autoregressive phases, can be seen as a system of dynamic substances that, in response to changes in entropy, through repeated processes of entropy increase and decrease, aggregate and disperse, rectify entropy, compete with and conserve each other, and co-evolve with systems that approach safety and move away from danger, the system as a whole evolves and be organized, thereby increasing its resistance to increases in entropy in its environment. This is the co-evolution of entropy and living systems in the direction of the time axis.

The evolution of living systems may have acted as a selection pressure on the mechanisms that are important for pumping out entropy in the system. For example, the pumping of substances that promote the destabilization of RNA molecules, the perceived presence of rocks with high buffering capacity, and proximity to them.

A zone of rocks of uniform composition can be considered as a system that adsorbs certain substances, precipitates certain substances, produces certain substances, and has certain

buffering capacities. Considering the role of rocks in living systems, they support the pumping out of entropy in living systems through the selective adsorption of materials and buffering.
When a spherical structure is under high temperature and high pressure conditions, what properties and dynamics does the center of the spherical structure have, which may be important for the analysis of life phenomena.
The central point of the vesicle may be viewed as a singularity and may be useful for analyzing its mechanism and function.
In order to elucidate the dynamism of entropy at the micro level of living systems, it may be important to analyze the three-dimensional motion of chain molecules and the associated mechanisms of energy conservation and consumption (including those carried by the elasticity and torsion of chain molecules), entropy absorption and exhaustion.
One might say that the genome in the bio system attempts to organize uncertainty (in this sense, how can viruses be explained?).
A fractal structure seems to be considered as a structure in which the micro and macro are harmonically connected and transformed along a time axis. In addition, a fractal structure may be said to be one in which the increasing and decreasing processes of entropy cancel each other. The mechanism by which such a fractal structure loosely connects past and future probability spaces may be explained by the Bethe approximation, in which the interference of three-dimensional waves in fractal space takes the shape of a Bethe lattice.
These mechanisms may be related to the attenuation of waves due to the superposition of waves in opposite phases and their cancellation by vectors in opposite directions, as well as the attenuation of momentum and interaction of sparse and dense waves.
It may be important to note that fractal structure retains its self-similar structure even after dimensional expansion and that it joins the limit and the center, and they are always similar in the form of past, present and future probability spaces with respect to the time axis direction of deepening.
There are simple questions about fractal structures. Is fractal structure brought about by an acceleration of the rate of expansion of the spacetime of the moving point from the center? What is the relationship between entropy and the behavior of a dynamical fractal structure in dynamical spacetime? Does a dynamic fractal structure provide corrective feedback to the Hamiltonian of its own motion vector?
If life phenomena are the growth process of fractal structures by recursive self-aggregation, what kind of mathematical equation can we generalize? Also, is the formation of the neck, which is an important fractal formation process, an important mechanism in life phenomena?
However, from the viewpoint that fractals can buffer the dynamism of environmental changes, what role and function do life phenomena play in the material cycle and homeostasis of the

earth? This seems to be significant subject to consider.
Since the microscopic processes of rhythmic phenomena, chaos, and descriptive models of chemical potentials can be represented by differential equations, what dimensions are variables, what properties are described, and what inferences can be made about macroscopic behavior in life phenomena as the edges of fluids, networks, and chaos? What inferences can be made about their macroscopic behavior?
Or what is the relationship between these and time space distortions?
It would be of great significance if it could be theoretically demonstrated that the integrals of microscopic processes of living systems co-evolve with time space distortions.
A system formed by the conjugation of an ever-diffusing system and an ever-cohesive system exhibits a non-equilibrium and irreversible change process. This can be regarded as a co-evolution of divergent and convergent processes. Stability and evolution of life phenomena and the mechanism of entropy extraction from the environment may be more clearly understood from such a viewpoint.
A living system may be said to be a dynamic system that learns, maintains, and predicts a model for pumping out entropy as structures oriented and arranged within a geometrically closed space of systems with the ability to travel, rectify, and attenuate against entropy form populations, hierarchical structures, and flow paths that support, select, and coevolve with one another.

Citation

Hatakeyama, Tetsuhiro Himeoka, Yusuke. (2023). An Introduction to Systems Biology. Kodansya. pp.111-112

Jacob N. Israelachvili. (2013). Inermolecular and Surface Forces Third Edition translated by Hiroyuki, Ohshima. Asakura publishing. p.521

Ohta, Takao. (2008). Physics of Nonequilibrium Systems 6th Edition (Author translation). Shokabo. p.105

O'NeillP. Murphy Luke A. J.Michael. (1995). What is Life? The Next Fifty Years Speculations on the future of Biology Japanese Edition translated by Hori, Hirokazu Yoshioka Toru. Cambridge University.

Rob phillips, Jane Kondev, Julie Theriot. (2011). PHYSICAL BILOGY OF THE CELL Japanese Edition translated by Sasai, Masaki Ito, Kazuhito, Chikenji, Johji, Terada, Tomoki. Kyoritsu shuppan. p.471

Serizawa Hiroshi. (2015). Mathematical models and complex systems using differential equations (Author translation). Gendaisugakusha. pp.112-113

Takayasu Hideki. (2020). Fractal Science New Edition (Author translatiion). Asakura Publishing. pp.63-67

Tsubota, Makoto Kasamatsu, Kenichi Kobayashi, Michikazu Takeuchi, Hiromitsu. (2018). Quantum Hydrodynamics. Maruzen publishing. pp197-198, 239-240

Uragami Dausuke Gunji, Yukio-Pegio. (2021). Intelligence Simulation with Cellular Automata (Author translation). Ohmsha. pp.94-97