Opinion and Perspectives

Earth's Orbital Chirality and Its Possible Role in Biomolecular Evolution

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Abstract

The natural Earth's orbital chirality (EOC) and its force field were described. According to the second law of thermodynamics, it was suggested that the EOC force field could be a natural driving force to result in the origin of biomolecular homochirality, the evolution of biomolecular order and complexity, the origin of "Junk DNA" and the origin of biological information and biomolecular rhythms.

Key Words: Earth's orbital chirality, driving force, biomolecular evolution, thermodynamics, rhythms

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Introduction

The origin and evolution of life is one of the most interesting puzzles on the Earth. This essay focused on the natural Earth's orbital chirality and its possible role in biomolecular evolution. Biomolecular evolution, as a physical-chemical process, has to satisfy the laws of thermodynamics.

Entropy (S) is a measure of the disorder (or degree of randomness) of a system. The second law of thermodynamics states that a process can occur spontaneously only if the sum of the entropies of the system and its surroundings increases (Stryer, 1995). As we know, there always is a decrease in the entropy of biomolecular evolution which seems to violate the second law.

The most transformations occur under conditions of constant pressure (P) and temperature (T). Gibbs created the free-energy (G) function by combining the first and second laws of thermodynamics. The equation for a system undergoing a transformation at constant P and T is given by (Stryer, 1995):

$$\Delta G = \Delta H - T\Delta S \qquad (1)$$

$$= (\Delta E + P\Delta V) - T\Delta S \qquad (2)$$

$$\cong \Delta E - T\Delta S \qquad (3)$$

where ΔG, ΔH and ΔS are the changes in free energy, enthalpy and entropy of this system, respectively. ΔE and ΔV are the changes in internal energy and volume of this system, respectively, and ΔV is approximately equals to 0 for nearly all biochemical reactions (Stryer, 1995).

The biomolecular evolution means $\Delta S<0$, and it can occur spontaneously only if the change in free-energy (ΔG) is negative in the above equations (1)-(3). It is the $\Delta G(<0)$ that is the thermodynamic "driving force" of spontaneous biomolecular evolution. However, what is the nature and source of the driving force, and how does it work?

In 1859 Charles R Darwin articulated the theory of natural selection and the concept of evolution in his famous "On the Origin of Species". His treatise, as well as those of Wallace, implied that the natural factors should play a key role in the origin and evolution of life.

At almost the same time, L. Pasteur postulated (Dubos, 1960; Haldane, 1960), life, as manifested to us, is a function of the asymmetry of the universe and of the consequences of this fact. He also thought that all living species are primordially in their

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structure and external forms that are consequences of cosmic asymmetry. It directly implied the important role of natural asymmetry in the origin and evolution of life.

According to our recent work (He, 1998; He, 2000; He, 2000; He, 2001; He, 2005; He, 2007), it was suggested that the natural chiral helical force field that produced by the Earth's orbital chirality (EOC) (Figure 1) is a natural factor that may have played a role as a driving force in both the origin of life and biomolecular evolution.

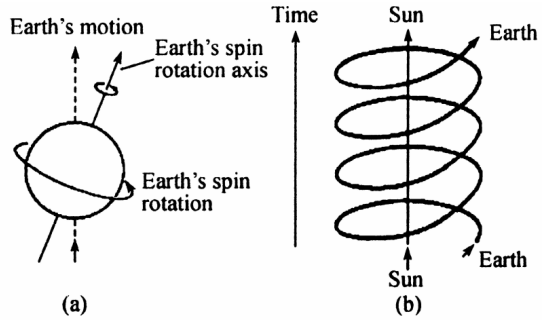

Figure 1. The natural right-handed helical Earth's orbital chirality and its force field. It is produced by both the Earth's right-handed helical rotation around its spin rotation axis (a) and the Earth's helical revolution around the Sun (b).

1. The natural Earth's Orbital Chirality

The helix is chiral. The chirality of a helix is defined in physical terms. If a spinning rotation (axial vector) is moving along its spin axis (polar vector), parallel and anti-parallel combinations of a polar and axial vector produce a right and left-handed helix, respectively (He, 2007).

In the solar system, the combination of the Earth's spinning and revolution (axial vector) and the Earth's motion toward Vega (polar vector) forms the right-handed super-helical motion with circadian, seasonal and annual periods in space-time. This creates the Earth's orbital chirality (EOC) and its corresponding EOC force field in which terrestrial life is living (Figure 1) (He, 1998; He, 2000; He, 2000; He, 2001; He, 2005; He, 2007; Rudaux, 1962). Unfortunately, the natural Earth's orbital chirality and its force field, as well as its effects, are almost ignored.

In the Earth's orbital chirality (EOC) force field, at any point on the Earth's surface, the total chiral helical centrifugal force of the EOC force field (F_{eoc}) that can act on the helical biomolecular residue (average mass in kg) should be given by (He, 1998; He, 2000; He, 2000; He, 2001):

$$F_{eoc} = \pm [F^2_{ee}+F^2_{es}-2 F_{ee}F_{es}\cos (180-\phi)]^{1/2} \quad (4)$$

$$= \pm m [3.5\times10^{-5}+2.8\times10^{-17}R^2_{ee}- 6.3\times10^{-11} R_{ee} \cos(15t) \cos(\varphi \sin(15t/365))]^{1/2} \quad (5)$$

where F_{ee} and F_{es} are the chiral helical centrifugal forces produced by the Earth's spin and revolution, respectively, R_{ee} is the shortest distance from the point on the Earth's surface to the Earth spin axis, ϕ is the angle (degree) between the F_{ee} and F_{es} at any given time and point, and φ is the Earth's obliquity (23.45°). The time t (hr) starts at 0 o'clock on the Spring Equinox (around March 21st).

According to equation (5), the F_{eoc} changes periodically in circadian and annual (seasonal) rhythms (Figure 2), which are caused by the cos(15 t) of the earth's helical spin and the cos(φ sin(15 t/365)) of the earth's helical revolution, respectively.

The EOC force field is chiral (right-handed helical), rhythmic (circadian and seasonal/annual), directional (vector), and weak. If the effects of other astronomical bodies are considered, the F_{eoc} equation should be more accurate. The EOC force field may act on chiral biomolecules via the chiral and rhythmic effects to play a role of the driving force in biomolecular evolution.

2. The interaction of the Earth's orbital chirality and biomolecules

As we know, the secondary structures of biomolecules (proteins and nucleic acids) generally are helically right-handed. What are the effects of the natural Earth's orbital chirality (EOC) on the biomolecules? According to our work (He, 1998; He, 2000; He, 2000; He, 2001), at a given point on the Earth's surface, the right-handed EOC force field could make the right-handed helical biomolecules more stable than corresponding left-handed enantiomeric ones. The maximum EOC stabilization energy of right-handed molecule could be given by:

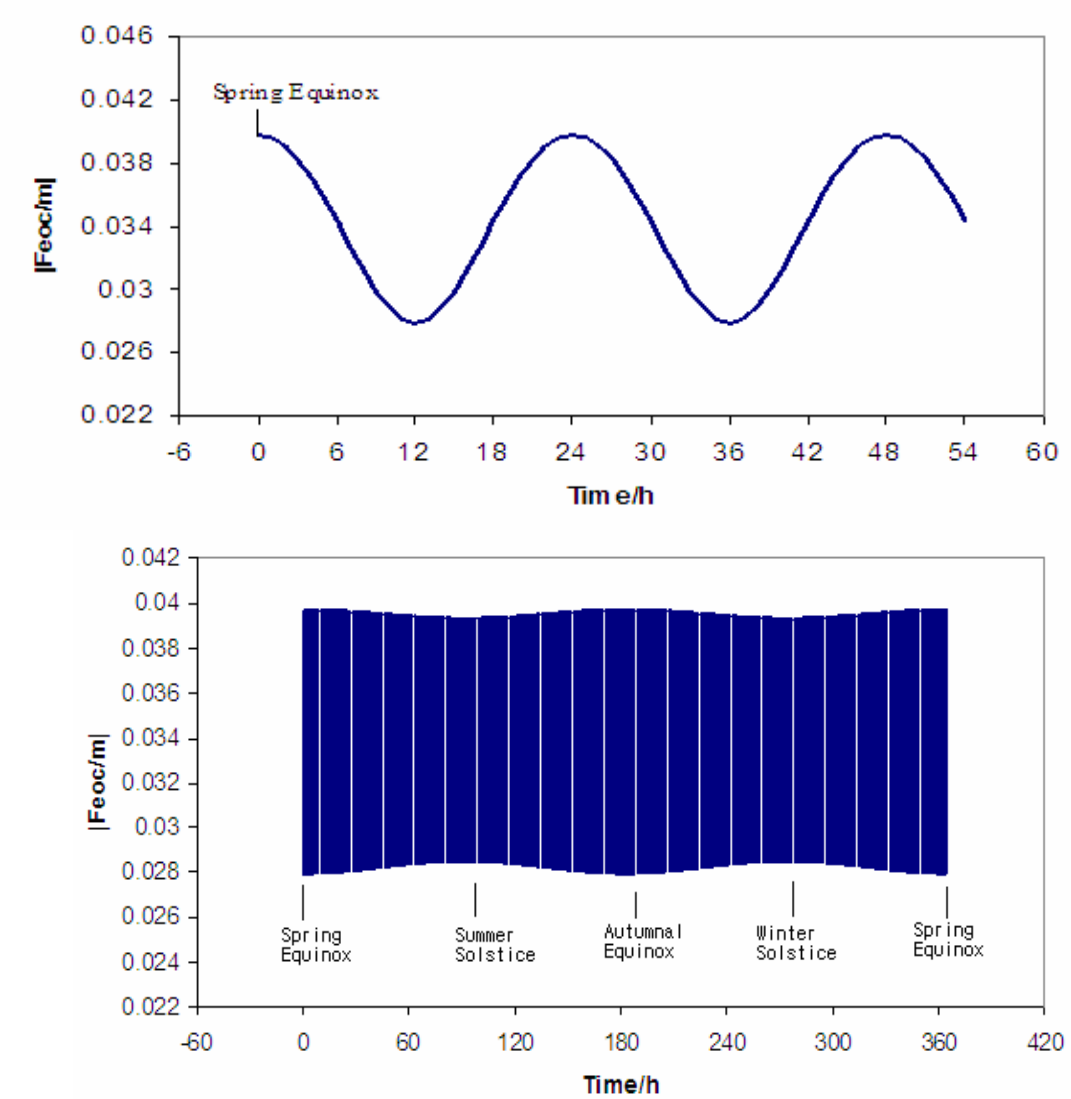

Figure 2. The circadian and annual (or seasonal) rhythms of $|F_{eoc}/m|$ at the equator (where R_{ee} = 6378 km)

$$\Delta E_m = \Sigma[0.5\,(R_m / \cos^2\theta_m)\,F_{eoc}+\eta_p F_{eoc}]_i \quad (6)$$

$$\cong \Sigma[0.5\,(R_m / \cos^2\theta_m)+\eta_p]_i\, m_i\, [3.5\times10^{-5} + 2.8\times10^{-17}R_{ee}^{2}-6.3\times10^{-11}R_{ee}\cos(15t)\cos(\varphi\sin(15t/365))]^{1/2}\ \text{(J/molecule)}(i = 1, 2, 3, \ldots, N) \quad (7)$$

where R_m, θ_m, N and m_i are the radius of molecular helix, the helical angle, the number and mass of molecular residues (amino acids or nucleotides) in helical biomolecule, respectively; η_p is the F_{eoc} potential energy factor; other parameters are the same as above for equation (5). It is noteworthy that there will be no EOC stabilization effect (ΔE_m = 0) if the molecule is achiral (R_m, η_p = 0).

For example, in equation (7), as to deoxynucleotide, its R_m, θ_m and m_i are about 1×10^{-9} m, 28.4° and 330 Dalton, respectively, and its stabilization energy $\Delta E_{max}\cong1.4\times10^{-35}$ J/monomer; as to amino acid, its R_m, θ_m and m_i are about 0.25×10^{-9} m, 19.0° and 127 Dalton, respectively, and its stabilization energy $\Delta E_{max}\cong 1.2\times10^{-36}$ J /monomer.

According to equation (7) and (3), the characteristics of the EOC force field (chirality, rhythmicity etc.) could be transferred to the helical biomolecules via the chiral interaction. Some puzzling features in biomolecular evolution could be integrated and interpreted in molecular thermodynamics.

3. The possible role of EOC force field in biomolecular evolution

3.1. As a driving force in evolution of biomolecular order and complexity

By the above equation (7), in order to get maximum EOC stabilization energy, the biomolecules would tend to increase N (i.e. an increase in molecular length) and preferentially select those residues and sequences (m_i, θ_m) that can form more stable structures. This means that the biomolecular evolution should be directional, rather than random. In other words, if given enough time, the biomolecules can spontaneously tend to form longer and more stable sequences and structures via the EOC stabilization effects. The EOC force field would have served as a natural driving force of biomolecular evolution. As a result, there would be greater molecular complexity and more stable biomolecules in the higher biological systems than in the lower ones (He, 2001).

In the EOC force field, the right-handed biomolecules (including these chiral elementary particles in molecules) are stabilized by the EOC stabilization energy effects ($\Delta E_m > 0$), and the biomolecular evolution would result in an increase in structural order ($\Delta S < 0$). The biomolecular ΔE_m could make the change in internal energy negative ($\Delta E = -\Delta E_m < 0$). Thus, ΔG is able to be negative under certain conditions although the ΔS is negative (i.e. increase in structural order) in equation (3).

Due to the biomolecular EOC stabilization energy effect, the spontaneous formation of a highly ordered biomolecular structure is thermodynamically feasible. It does not violate the second law. In fact, the origin of biomolecular homochirality can be as the spontaneous formation of primary structural order (He, 1998).

3.2. As a driving force in the origin and evolution of biomolecular homochirality

Pasteur postulated that the peculiar selectivity of living processes for one or the other of isomeric forms of the same molecule might be the manifestation of asymmetric forces of the environment acting upon the living organism during the synthesis of protoplasmic constituents (Dubos, 1960). Also, this molecular asymmetry perhaps is the only sharply defined difference between the chemistry of dead and of living matter (Dubos, 1960).

On the Earth, the biological systems are based on D-sugars and L-amino acids rather than L-sugars and D-amino acids, i.e. homochirality (He, 1998). It is the major structural order requirement in biomolecular evolution, as well as in the origin of life. The hypothesis indicates that the cause that gave rise to the origin of biomolecular homochirality is the Earth's orbital chirality (EOC) whose force field is a natural asymmetric force of the environment acting upon biomolecules (He, 1998).

The right-handed helical EOC force field could theoretically make the right-handed helical secondary structures more stable than the corresponding left-handed helical ones. Terrestrial living systems should select both right-handed helical nucleic acids based on D-sugars (rather than L-sugars) and right-handed helical proteins based on L-amino acids (rather than D-amino acids). The experiments on the effects of helical force on DNA (He, 1998) and protein (RNase A) supported the hypothesis (Figure 3). The right- and left- handed helical force stabilized and unstabilized the right-handed helical RNase A, respectively.

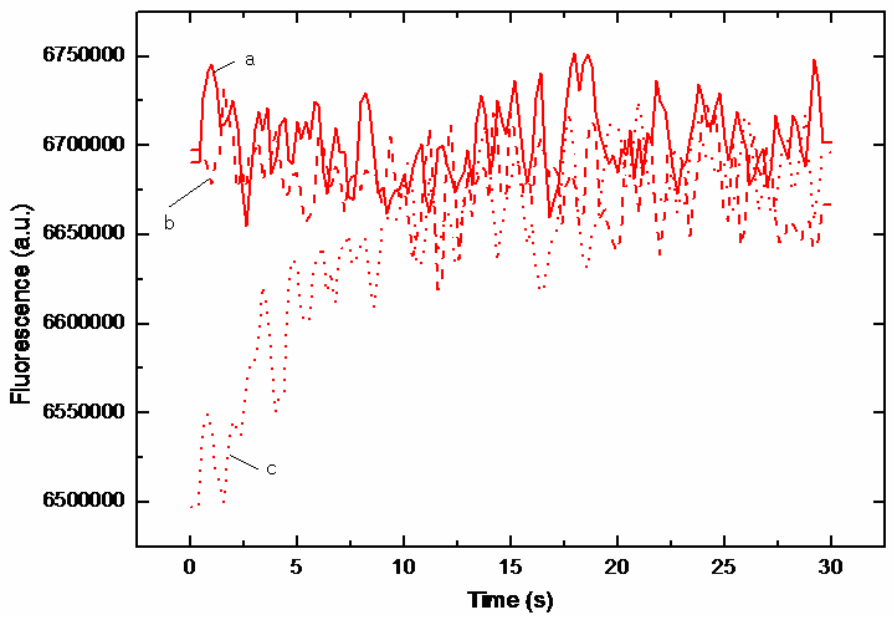

Figure 3. The changes in RNase A stability after acted on by the right- (a) and left- (c) handed helical force compared with natural force condition (b) (λ_{ex} = 285 nm, λ_{em} = 309 nm). The lower (higher) the fluorescence of RNase A is, the lower (higher) its stability is.

3.3. As a driving force in the origin and evolution of "Junk DNA"

A striking feature of the genomes of higher eukaryotes is the abundance of repeated DNA sequences and the small proportion of protein-coding DNA sequences. The non-coding repetitive DNA sequences are called "Junk DNA" or introns. In equation (7), the bigger the N is, then the larger the ΔE_m is. It implies that DNA favors longer stranded structure in the EOC force field. Thus, the "Junk DNA" in genomes of higher biological systems might be as a result of the continuous effects of the EOC force field on genome evolution via the EOC stabilization. Consequently there is more "Junk DNA" in higher living systems than in the lower ones (He, 2001). The "Junk DNA", in turn, could increase genomes stability and complexity in life.

3.4. As a driving force in the origin and evolution of biological information

In the origin of life, the origin of biomolecular information is one of the fundamental puzzles. Under prebiotic conditions, a defined sequence of molecular symbols, the nucleotide sequence of the protogene, was selected out of an innumerable multitude of physically equivalent alternatives (Küpper, 1990).

In above equation (7) and (3), the biomolecular EOC stabilization energy (ΔE_m) is dependent on its structural parameters (m_i, N, R_m, θ_m and η_p etc.) under certain environmental conditions (T, t and R_{ee} etc.). The different nucleotide units and sequences that can make different structural parameters in molecule would have different effects on the molecular EOC stabilization energy. In order to have maximum stabilization energy, the protogene molecules would preferentially and spontaneously select these special nucleotide sequences to form more stable structures.

Of course, because of the EOC effect, these protogenes should satisfy the homochirality and have the circadian and annual (seasonal) rhythms of the EOC (He, 1998; He, 2000). This means that the formation and evolution of protogene sequences were selective and instructional, rather than random and equivalent. Therefore, the highly conceptual biological information could spontaneously be produced by the chiral interactions of the protogenes with the EOC force field under prebiotic conditions to result in the origin of biological information (He, 2001).

3.5. As a driving force in the origin and evolution of biomolecular rhythms

According to equations (5) and (7), the biomolecules would be always acted upon by the EOC to have the circadian, seasonal/annual rhythms. The data depicted in Figure 4 strongly supports this predication. In Figure 4, the stabilities of RNase A and DNA dA•dT-Ethidium bromide under constant conditions are satisfied with the well-known circadian rhythm criteria: (a) ~24-hour period; (b) persistence under constant conditions; (c) temperature compensation; (d) entrainment to the exogenous EOC circadian rhythm etc. (He, 2000). It indicated that the chiral interactions of the rhythmic EOC force field with the chiral biomolecules could give rise to the periodicity of the biomolecular stability to result in the origin of biological rhythms in terrestrial living systems (He, 2000). It was also demonstrated that the EOC force field could cause the rhythms and symmetry breaking in radioactive processes (He, 2005; He, 2007; Haldane, 1960). This indicates the EOC effects should be universal on different levels (He, 2000).

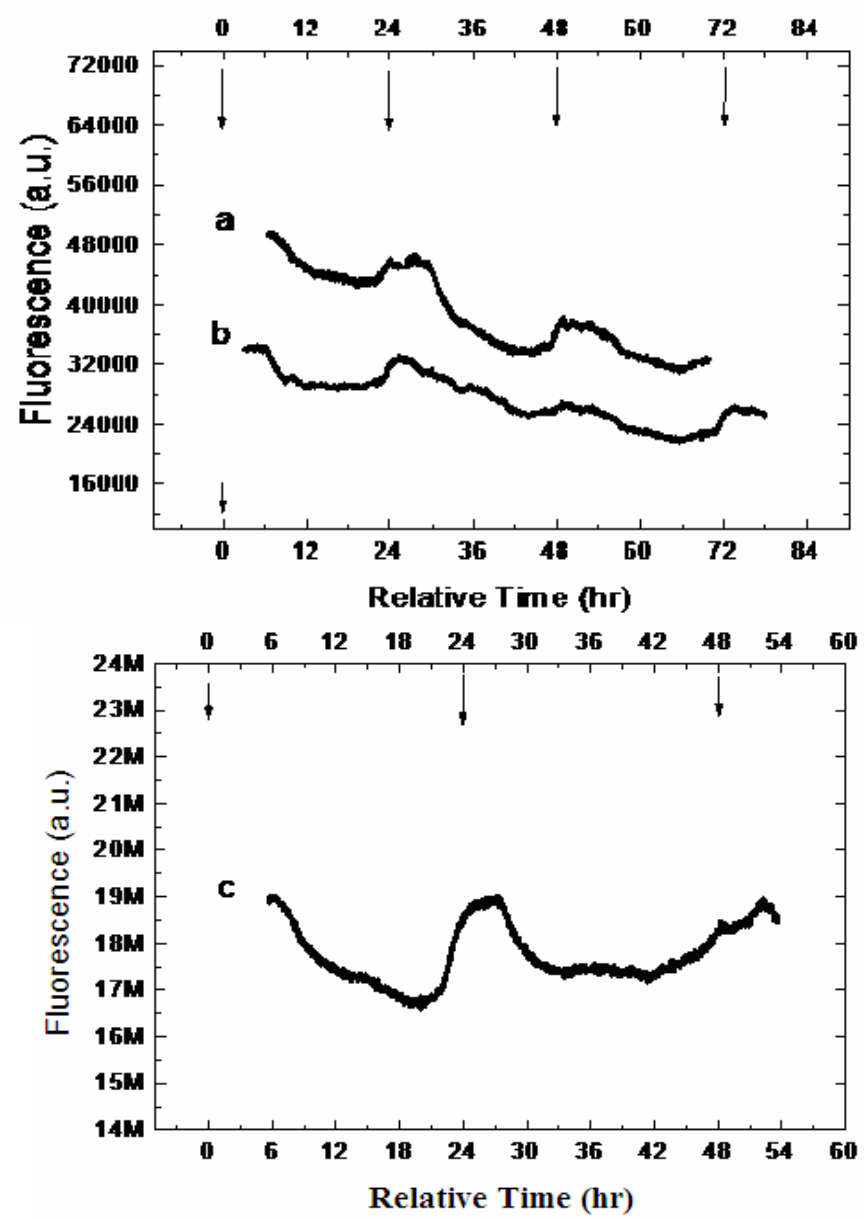

Figure 4. The circadian rhythms of the stabilities of protein (RNase A) at 30°C (a) and at 37°C (b), DNA (dA•dT)-Ethidium bromide at 24°C (c) under constant conditions.

4. Summary

All terrestrial living beings, including ourselves, are living in the natural EOC force field. It was thermodynamically suggested that the EOC force field could be a natural driving force of biomolecular evolution via chiral interaction to affect the biomolecular structure (homochirality/structural order), their functions (stability/activity) and behavior (circadian/annual rhythms). This produced a spontaneous evolutionary direction from the domains of simple and disorder to complex and highly order. In the future, it should be valuable and interesting to further explore the possible thermodynamically feasible role of the EOC force field in molecular self-organization and assembly, chiral synthesis, biomolecular folding and even in the metabolic pathways. The EOC may be a unifying factor for chirality and rhythms on different levels, and so on (He, 2000; He, 2007).

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