The driving force and progressive mechanisms of evolution deduced from thermodynamics

Ji-Ming Chen*

China Animal Health and Epidemiology Center, Qingdao, 266032, China

*** Corresponding author.**
Email: jmchen678@qq.com
Telephone: +86-13854212160.
ORCID: https://orcid.org/0000-0002-0404-0830

Abstract

Studies on evolution have made significant progress in multiple disciplines, but evolutionary theories remain scattered and controversial. Here we deduce that, thermodynamically, many carbon-based entities (CBEs) on the Earth tend to absorb energy from widespread relatively temperate heat streams on the Earth flowing from the solar, geothermal, and other energy sources, to form higher-hierarchy CBEs (HHCBEs). This has been the driving force of evolution leading to accumulation of HHCBEs for billions of years. We further deduce three progressive mechanisms of evolution including natural selection from the driving force. We hence establish the CBE evolutionary theory (CBEET) which reinterprets the major aspects of evolution in a comprehensive and comprehensible way. The CBEET provides novel explanations for natural selection, origin of life (abiogenesis), macroevolution, sympatric speciation, and evolutionary tempos. It suggests that evolution is driven hierarchy-wise by thermodynamics and favors fitness and diversity. It elucidates that altruism, collaboration, and obeying rules with balanced freedom are important throughout the CBE evolution which includes chemical evolution, biological evolution, and animal group evolution. The CBEET refutes several erroneous views including negative entropy and survival of the fittest. It integrates with research advances in multiple disciplines and links up laws of physics, evolution in biology, and harmonious development of human society.

Keywords

driving force; energy; evolution; fitness; mechanism; natural selection; speciation; thermodynamics; theory

1. Introduction

In recent decades, our knowledge regarding origin of life and biological evolution has been updated greatly with the development of biology, geology, physics, and astronomy [1-7]. However, evolutionary theories remain scattered, controversial, and inadequate to interpret some evolutionary conundrums including mechanisms for origin of life, macroevolution, evolutionary tempos, and sympatric speciation [1-13]. It is hence desirable to develop a novel evolutionary theory which can integrate with research advances in multiple disciplines and explain some evolutionary conundrums in a comprehensive and comprehensible way [1-13].

This article aims to deduce such a theory. It pertains to the evolution of carbon-based entities (CBEs), and is hence termed the CBE evolutionary theory (CBEET). The differences between the CBEET and previous theories are outlined in **Figure 1** and listed in **Table 1**.

2. Methods

2.1 Definitions

CBEs, HHCBEs, LHCBEs: CBEs are the molecules or other entities based on carbon atoms, including some small molecules containing carbon atoms (e.g. methane and ethanol), middle organic molecules (e.g. amino acids and nucleotides), large organic molecules (e.g. proteins and nucleic acids), and organisms (e.g. bacteria, animals, and plants). CBEs have hierarchies, and large organic molecules are higher-hierarchy CBEs (HHCBEs) compared with middle organic molecules, but they are lower-hierarchy CBEs (LHCBEs) compared with organisms.

Multiple other concepts including the extrapolation logic, the deduction logic, the backstepping logic, microevolution, macroevolution, altruism, natural selection, positive selection, negative selection, punctuated equilibrium, chemical evolution, animal group evolution, and cultural evolution are defined at relevant sites in this article.

2.2 Deduction logics

Previous evolutionary theories and researches were established on the extrapolation logic. This logic assumes that regularities of the evolution within species (microevolution) are applicable to the evolution above the species level (macroevolution) [3-5,14]. This logic was established on observations regarding the differences, similarities, and relationships in biological traits, structures, functions, fossils, genetics, and epigenetics. They do not mention energy transformation which is the driving force of almost all changes.

The CBEET was established not only on the extrapolation logic stated above, but also on the deduction logic. It employed laws of thermodynamics and other facts that are applicable to the ranges larger than evolution, to deduce regularities of evolution (see **Section 3**). The CBEET relies on energy transformation. Additionally, the backstepping logic was employed to deduce the major steps of evolution (see **Section 5**).

Detailed deduction processes were given at relevant sites in **Sections 3–10**. The laws of thermodynamics and the deduction of the CBEET from thermodynamics are detailed in **Supplementary File.**

2.3 Validation

The major views of the CBEET are validated through one or two ways: whether the views can explain some phenomena which have not been well explained; whether the views reflect the reality better. Streamline application of the CBEET in the whole evolutionary process described at **Sections 6–9** also validated the CBEET.

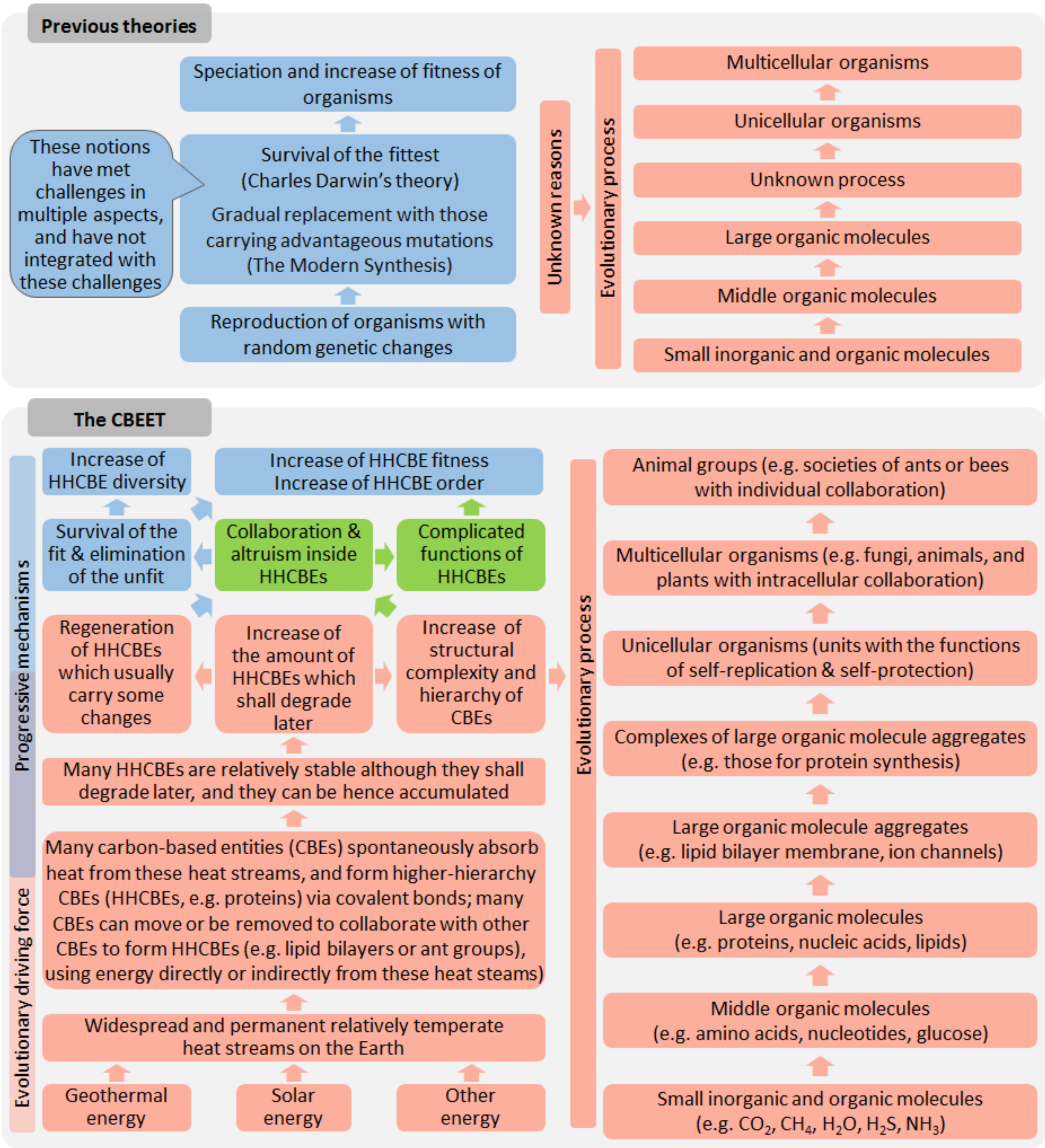

Figure 1. Major views of the evolutionary theory CBEET versus previous theories.

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 20 November 2020 doi:10.20944/preprints202010.0004.v4

Table 1. Differences between the evolutionary theory CBEET and previous theories.

Topics	Previous theories	CBEET views
Logic	Extrapolation from microevolution	Extrapolation from microevolution and deduction from thermodynamic laws
The driving force of evolution	Natural selection, genetic drift, mutation, or competition (none of them provide energy)	The tendency of carbon-based entities (CBEs) to absorb energy from heat streams on the Earth to form higher-hierarchy CBEs (HHCBEs)
Progressive mechanisms of evolution	Natural selection, sexual selection, and epigenetic changes lead to increase of fitness of organisms; no rational mechanisms have been proposed to interpret macroevolution	The driving force increases the structural complexity and hierarchy of CBEs; CBEs with increased structural complexity and hierarchy can obtain spontaneously some complicated functions; natural selection leads to increase of diversity and fitness of HHCBEs
Order in biology	Organisms have order and low entropy due to negative entropy (input of low-entropy matter and output of high-entropy matter)	Organisms are of high entropy; the notion of “negative entropy” is wrong; order in biology is contrary to order in physics; order should not be always hooked with low entropy
Natural selection	Defined as “survival of the fittest” or “gradual replacement with those carrying advantageous mutations”; usually focusing on positive selection in one aspect; mutations occur randomly; only inheritable changes are under natural selection	Defined as “survival of fit HHCBEs and elimination of unfit HHCBEs”; highlighting the overall fitness constituted by all traits of HHCBEs; highlighting selection from various aspects; some mutations occur not randomly; inheritable and uninheritable changes (e.g. vaccination) are all under natural selection
Chemical evolution	Neither the driving force nor the mechanisms have been proposed to interpret how large organic molecules evolved into lives	The driving force and mechanisms of chemical evolution are revealed; lives originated stepwise from small molecules to middle organic molecules, large organic molecule aggregates, and complexes of large organic molecule aggregates
Biological evolution	Interpreting the punctuated equilibrium tempo using geological isolation; interpreting sympatric speciation with diverging selection targeting different niches in the same area	Interpreting the punctuated equilibrium tempo with genetics and via natural selection in multiple aspects, covering the effects of geological isolation and temporal changes; proposing a novel sympatric speciation mechanism which targets the same niche through different combinations of traits
Animal group evolution	Not having established the concept of animal group evolution and relevant views; difficult to explain altruism and social norms; stressing selfishness, competition, and survival of the fittest; negative influence on human society	Establishing animal group evolution as a phase of the evolution; clarifying that altruism, collaboration, and obeying rules with balanced freedom are important throughout the evolution of CBEs; clarifying that struggles are crucial to maintaining animal groups, and that altruism and collaboration are critical for winning and avoiding struggles
General features	Not relying on energy, scattered, prejudiced, elusive, colliding with relevant disciplines	Heavily relying on energy, inclusive and integrated, comprehensive, comprehensible, bridging physics, biology, and social sciences

3. The driving force of evolution

The earth's surface has widespread relatively temperate heat streams from sunlight and geotherm. The earth, as a rare habitable planet in astronomy, is in a suitable orbit and receives temperate sunlight, which leads to temperate heat streams on the Earth for billions of years [14]. Meanwhile, many sites on the Earth, particularly at hydrothermal vents, have emitted geothermal energy for millions of years [15,16]. The huge amount of water on the Earth and the atmosphere of the Earth regulates solar energy and geothermal energy through evaporation, diffusion, and rainfall, making them more temperate, last longer, and distributed more widely.

The widespread relatively temperate heat streams on the Earth trigger many energy-absorbing changes, according to the second law of thermodynamics (i.e. heat can spontaneously flow from a hotter location to a colder location) [17,18]. Stones can spontaneously absorb heat from these heat streams and increase their temperatures, and many CBEs can spontaneously absorb heat from these heat streams to form HHCBEs through covalent bonds, partially because carbon atoms are apt to form covalent bonds after absorbing heat [19]. Meanwhile, many CBEs are mobile (e.g. many organic molecules are soluble in water, and they can move with water flow), they can hence meet and collaborate with other CBEs to form HHCBEs not through covalent bonds (e.g. lipid molecules can form bilayer membranes in this way, and ant individuals form ant groups also in this way). Energy directly or indirectly from the widespread relatively temperate heat streams on the Earth is usually required for the movement of CBEs to form HHCBEs in this way.

Although all HHCBEs shall degrade sooner or later, many HHCBEs are relatively stable, and they are hence accumulated. For this reason, HHCBEs have been accumulated at a myriad of places for billions of years, due to the widespread relatively temperate heat streams on the Earth, which constitutes the evolution of CBEs (**Figure 1**). Therefore, the tendency of CBEs on the Earth to absorb energy to form HHCBEs, is the driving force of evolution (see **Supplementary File**).

Initially, the driving force of evolution was from solar energy and geothermal energy. Later, with the increase of organisms on the Earth, biological energy became a source of the driving force of evolution (**Figure 1**). This is of paramount significance for animals which can actively obtain energy and materials from other organisms. As for humans, energy from coal, petrol, water flow, and even nuclear power has been utilized for the development of human society which is also an HHCBE system.

The above driving force can explain why non-living organic molecules evolved to lives, why unicellular organisms evolved to multicellular organisms, and why ectotherm animals evolved to warm-blooded animals, because all these three macroevolution events were the processes where CBEs on the Earth absorbed energy and formed HHCBEs. They cannot be explained convincingly with previous theories including natural selection, because none of the processes added fitness to CBEs [3-5,10,20,21].

During the whole history of the Earth, the amount and the diversity of HHCBEs including organisms on the Earth are generally increasing [22]. However, meteorite impacts, huge volcano eruptions, long glacial periods, and other catastrophes can destroy the temperate heat streams on the Earth and structures of many organisms [23-25]. Consequently, the amount and the diversity of organisms could decline greatly for the catastrophes, sometimes leading to mass extinctions [23-25].

4. Progressive mechanisms of evolution

4.1 Three progressive mechanisms

There are three progressive mechanisms for evolution, which explain why the complexity, hierarchy, diversity, functions, fitness, and order of CBEs are increasing naturally (**Figure 1**). The first is termed the driving force mechanism shown with the red arrows in **Figure 1**, where the driving force of evolution directly raises the amount of HHCBEs and increases the structural complexity and hierarchy of CBEs. The second is termed the structural mechanism shown with the green arrows in **Figure 1**, where CBEs with increased structural complexity and hierarchy spontaneously obtain some complicated functions, due to collaboration and altruism of the components inside HHCBEs (altruism is the action supporting the existence and production of other entities). For example, when green fluorescence protein is formed by amino acids, it obtains spontaneously the function of emitting green fluorescence, due to collaboration of its amino acid components which all "sacrifice" their freedom to the protein. The third mechanism is termed natural selection shown with the blue arrows in **Figure 1**, which leads to increase of the diversity and the fitness of CBEs, as detailed below.

4.2 The CBEET definition of natural selection

As shown in **Figure 1**, the driving force of evolution leads to formation and accumulation of HHCBEs. The formed HHCBEs are usually vulnerable and shall degrade into LHCBEs sooner or later, due to outer factors (e.g. fire burning) or inner factors (e.g. natural aging of CBEs) [1,2]. Therefore, lots of CBEs on the Earth are in the cycle of formation and degradation of HHCBEs, leading to regeneration of HHCBEs. Regenerated HHCBEs usually carry some changes which influence the overall fitness of HHCBEs.

Some regenerated HHCBEs are formed faster and/or degrade more slowly than some other HHCBEs. This leads to difference between HHCBEs in amounts, and some HHCBEs become extinct, while some others become populous, resulting from the overall fitness of HHCBEs based on collaboration and altruism of components of HHCBEs. The overall fitness of HHCBEs is also determined by the surroundings. For example, great fitness in a hot rainforest can be a terrible burden in a cold desert.

Natural selection is defined in the CBEET as survival of fit HHCBEs and elimination of unfit HHCBEs. When the environment is comfortable, the threshold of natural selection is low, which allows survival of HHCBEs carrying various changes [26]. In contrast, the threshold of natural selection increases greatly when a catastrophe occurs, which can lead to mass extinction of organisms including those quite fit previously [23-25].

4.3 Comparison with previous definitions

The CBEET definition of natural selection maintains the core feature of the concept of natural selection in Charles Darwin's evolutionary theory and in the Modern Synthesis [3-5]: fitness of organisms increases over time because natural elimination of the unfit, making unfit

HHCBEs survive less time and/or reproduce fewer progenies. The CBEET definition of natural selection is also different from previous definitions in multiple aspects.

First, the CBEET definition covers non-living CBEs and is thus more inclusive than previous definitions, and can be extended to chemical evolution (see **Section 5**).

Second, as shown in **Figure 1**, complicated functions, fitness, and order of HHCBEs are all based on collaboration and altruism of components inside HHCBEs which are influenced by changes of HHCBEs and under natural selection. Moreover, all these processes can be deduced from laws of thermodynamics. Therefore, unlike that natural selection in previous theories is supported by itself and hence suspected of tautology [27], natural selection in the CBEET is supported by the structures of HHCBEs and laws of thermodynamics.

Third, the CBEET definition (survival of fit HHCBEs) reflects the reality correctly, and is less harsh and more inclusive than "survival of the fittest" in Charles Darwin's theory and "gradual replacement with those carrying advantageous mutations" in the Modern Synthesis [1-4]. The CBEET definition is hence consistent with the research advances in molecular biology which suggest that most genomic changes are likely neutral without increase in fitness [3-5,10,12,28].

Fourth, the CBEET definition of natural selection highlights the overall fitness because the reality is that the existence of an HHCBE is determined by its overall fitness, although a certain trait may play a leading role in the overall fitness of an HHCBE. Therefore, the CBEET allows an organism to have disadvantageous traits, if its overall fitness is adequate. For example, antelopes are less strong than buffaloes to fight against carnivores, but they run fast and have other advantages, making them have adequate fitness in general.

Fifth, genetic mutations, epigenetic changes, and uninheritable changes all influence the overall fitness of HHCEBs, and they are thus all under natural selection. For example, vaccination which is uninheritable makes many animals survive viral infections and pass the relevant natural selection.

Sixth, previous definitions usually assume that mutations under natural selection occur randomly. Now it has been known that many organisms have the complicated function which makes many mutations occur not randomly, as evidenced in the evolution of microbial genomes and mammalian immunoglobulin genes [9,29].

4.4 Positive selection and negative selection

Organisms accumulated much fitness through long geological periods. Therefore, most traits of organisms are under both positive selection (supporting those changes which add fitness) and negative selection (inhibiting those changes which reduce fitness) [30].

Because natural selection "selects" organisms as per their overall fitness influenced by all genomic sites and all traits, all genomic sites and all traits are under both positive selection and negative selection [30,31]. Accordingly, natural selection functions extensively in evolution. Moreover, a conserved trait or genomic site without change during a long geological period does not mean that the trait or site is not under natural selection, but likely under strong negative selection [30].

A trait could add fitness in some aspects, but reduce fitness in other aspects, and a trait could reduce fitness in various aspects if it is out of a rational range. For example, proper increase of stature could facilitate herbivores to discover carnivores, but makes herbivores unable to run fast to avoid being captured, and too high herbivores are unfit in more aspects than avoiding being captured. Therefore, the stature is under the positive selection for early discovery of carnivores and the negative selection for keeping fitness in some other aspects.

5. The process of the evolution

The driving force of evolution from thermodynamics leads to formation and accumulation of HHCBEs hierarchy by hierarchy. For example, amino acids, nucleotides and other middle organic molecules could not bypass the intermediate hierarchy of large organic molecules to form unicellular organisms, and large organic molecules could not bypass the intermediate hierarchy of unicellular hierarchy to form multicellular organisms. Accordingly, as per the backstepping logic (i.e. if hierarchy A exists, the hierarchies lower than hierarchy A should have existed in advance), there should be the following seven major steps to constitute the whole evolution of CBEs on the Earth (**Figure 1**).

Step 7, many animal individuals of the same species collaborate with each other and form animal groups, which include societies of bees, ants, humans, and many other animals. These animal groups are under natural selection because they are formed and maintained at different rates. Meanwhile, CBEs below the hierarchy of animal groups, including animal individuals, cells, large organic molecules including genes, are also under natural selection along with animal groups. If a type of animal group is favored by natural selection, these LHCBEs involved in the formation of the animal group are also favored by natural selection.

Step 6, many cells collaborate with each other and form multicellular organisms, which include fungi, plants, and animals. Multicellular organisms are under natural selection because they are formed and maintained at different rates. Meanwhile, CBEs below the hierarchy of multicellular organisms are also under natural selection along with multicellular organisms, if they are involved in the formation of multicellular organisms.

Step 5, many complexes of large organic molecule aggregates collaborate with each other and form the first batch of unicellular organisms, which are the units having the complicated functions of self-replication via catalysis (for efficient generation of HHCBEs) and self-protection (for maintaining HHCBEs). These complexes constitute multiple types of organelles in the unicellular organisms, and each type of organelles could fulfil a complicated function, like synthesis of proteins, or synthesis of nucleic acids, or generation of adenosine triphosphate. Unicellular organisms are under natural selection because they are formed and maintained at different rates.

Step 4, many large organic molecule aggregates collaborate with each other and form complexes of large organic molecule aggregates which, like organelles in the unicellular organisms, have some complicated functions, like synthesis of proteins, or synthesis of nucleic acids, or generation of adenosine triphosphate. These complexes are under natural selection because they are formed and maintained at different rates.

Step 3, many large organic molecules collaborate with each other and form large organic molecule aggregates, including the aggregates of lipid bilayer membranes and the aggregates allowing ions to pass lipid bilayer membranes [32]. From this step to the seventh step, energy is not always required to form chemical bonds, but is required for the movement of CBEs to meet and collaborate with other CBEs. Large organic molecule aggregates are under natural selection because they are formed and maintained at different rates.

Step 2, many middle organic molecules collaborate with each other and form proteins, nucleic acids, polysaccharides, and other large organic molecules. Large organic molecules are under natural selection because they are formed and maintained at different rates. Before origin of life, few templates or mechanisms were available to direct the synthesis of large organic molecules according to certain orders, and so proteins, nucleic acids, lipids, polysaccharides were produced with few repetitions, and thus the products were of a myriad of diversity. These highly diversified large organic molecules could provide abundant kinds of candidates for forming HHCBEs in **Steps 3–7**. This was beneficial for complexes of large organic molecule aggregates to form unicellular cells at a tiny possibility.

Step 1, many small molecules (e.g. CO_2, CH_4, H_2O, H_2S) collaborate with each other and form middle organic molecules (e.g. amino acids, nucleotides, glucose). This step has also occurred on other planets, and lots of middle organic molecules were sent to the Earth by meteorites [33]. Middle organic molecules are under natural selection because they are formed and maintained at different rates [34].

Steps 1–5 constitute chemical evolution which is also termed abiogenesis or origin of life. Steps 5–6 constitute biological evolution in a narrow sense. Step 7 constitutes animal group evolution including the development of human society.

6. Application in chemical evolution

The concept and relevant theories regarding chemical evolution were first proposed by Alexander Oparin [35]. Many aspects of chemical evolution have been investigated in recent decades using experimental and theoretic tools from chemistry, geology, and astronomy [3-5]. It has been revealed that meteorites could have brought lots of organic molecules to the early Earth, including polycyclic aromatic hydrocarbon (PAH), amino acids, sugar, adenine, and guanine [33]. Also, billions of tons of these middle organic molecules could have been formed from small molecules, particularly at hydrothermal vents and volcanic hot springs on the Earth [15,16,35]. Moreover, the possible routes for the formation of large organic molecules, e.g. proteins, DNA, RNA, polysaccharides and lipids on the early Earth have been widely explored [36]. However, the process and mechanisms for large organic molecules to combine to form the first batch of lives remain enigmatic, although the RNA world, hypercycle, collectively autocatalytic sets, and other evolutionary hypotheses have been proposed [37,38].

The five steps (Steps 1–5) mentioned above constituting chemical evolution increased the structural complexity of HHCBEs. The HHCBEs with increased structural complexity spontaneously obtained novel complicated functions. This led to origin of the first batch of lives which had the complicated functions of self-replication via catalysis and self-protection. Compared to non-living CBEs at the similar hierarchies in the similar surroundings, lives are much more efficient in maintaining their existence due to their complicated functions of self-replication and self-protection, and they have hence accumulated to huge amounts.

The five steps constituting chemical evolution suggest that, before origin of the first batch of lives, there were five successive and overlapping worlds: the world of small molecules, the world of middle organic molecules, the world of large organic molecules, the world of large organic molecule aggregates, and the world of complexes of large organic molecule aggregates.

Compared with previous views which emphasized the special role of RNA and some organic molecules with the function of autocatalysis [37,38], the CBEET highlights collaboration and altruism of various molecules.

7. Application in biological evolution

The CBEET reveals the driving force and progressive mechanisms of biological evolution. It also sheds novel insights into evolutionary tempos and speciation.

7.1 Evolutionary tempos

Many species have shown the evolutionary tempo of punctuated equilibrium, which means little change in long geological periods interrupted by short geological periods with significant changes [3-5]. There could be two reasons for this evolutionary tempo. First, organisms could change greatly in phenotype due to only one genetic or epigenetic change [2-5,39-42], and an organism carrying a significant change in phenotype can pass natural selection if it has adequate fitness. Second, if a trait in phenotype is inheritable, and the trait changes gradually generation by generation, and the change is favored by positive selection or sexual selection, then a significant change can be accumulated within a short geological period (e.g. increase by 1 cm in stature per generation can lead to increase by 10 m in stature in 1000 generations which can be fulfilled in a short geological period). When the change in this trait shall not add fitness in general, the trait shall maintain stability for a long geological period due to negative selection, demonstrating the tempo of punctuated equilibrium (**Figure 2**). Previously punctuated equilibrium was interpreted using geographic isolation [3-5], and here the CBEET provides a novel rational explanation for the tempo based on natural selection, which covers the effect of geographic isolation and the effect of temporal changes (e.g. climate changes).

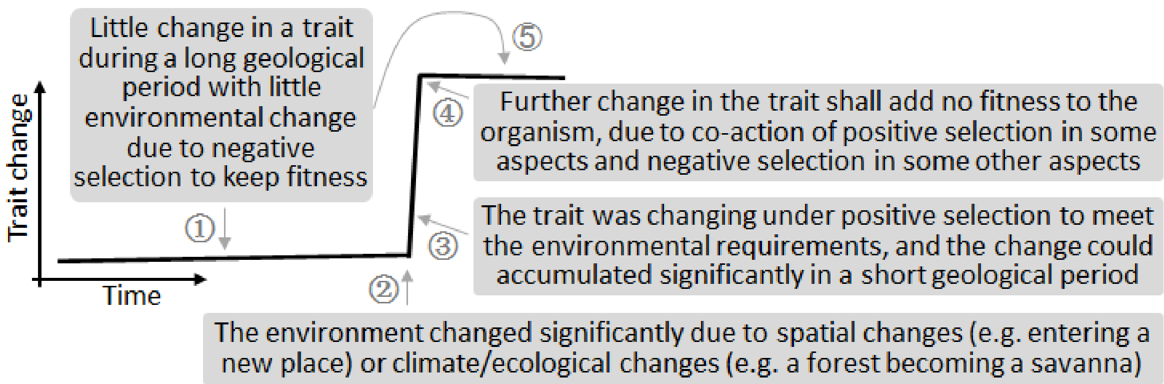

Figure 2. Reasons for the punctuated equilibrium tempo

7.2 Sympatric speciation

Allopatric speciation is important and easily comprehensible, while sympatric speciation is less comprehensible [43]. Different traits are required to obtain different sources of energy and food in the same area. This can result in sympatric speciation, and could have led to sympatric speciation in some insects that become dependent on different host plants in the same area [3].

The CBEET underlines overall fitness rather than a single trait. This suggests a novel mechanism of sympatric speciation, because multiple combinations of traits can all have adequate fitness in obtaining the same source of energy and food, or occupying the same ecological niche in the same area. This could have led to sympatric speciation of buffalos and antelopes, both of which rely on grazing and avoiding being killed by carnivores. Buffalos employ the combination of large stature and great defensive capability, while antelopes employ the combination of small stature and rapid running capability.

8. Application in animal group evolution

Animal group evolution was extended from biological evolution. The major role in biological evolution for direct collaboration and struggles for energy and materials is individuals of organisms, while the major role in animal group evolution for direct collaboration and struggles for energy and materials involves groups of animals.

Many species of animals have formed groups. Individuals in groups of bees, lions, and humans are willing to sacrifice themselves for fighting against invaders. Many mammals care for their progenies for months. They thus show collaboration and altruism in animal groups.

As shown in **Figure 1** and **Section 5**, collaboration and altruism of components provide fitness for HHCBEs throughout the CBE evolution, and hence it is comprehensible that animal groups rely on collaboration and altruism of individuals of organisms. Previous evolutionary theories have not established the evolutionary phase of animal group evolution, and they explain collaboration and altruism of animal individuals using the tenet of selfish genes or inclusive fitness [44]. The tenet of selfish genes or inclusive fitness is largely rational because animal genes are under natural selection along with animal groups.

Animal groups have novel functions which cannot be fulfilled by individual organisms. For example, some ant groups can have agriculture (planting fungi for food) or husbandry (raising aphids for collecting honeydew as food) [45]. Another advantage of animal groups is that struggles among individuals of the same species living closely are somehow avoided.

Some animal groups are eusocial, where some individuals reduce their own lifetime reproductive potential to raise the offspring of others. Many other animal groups are presocial, where the parents take care of their own progenies [46]. Although presocial species are much more common than eusocial species, eusocial species have disproportionately large populations [46], which supports the above notion that altruism and collaboration inside groups can add fitness to animal groups.

Besides collaboration and altruism, struggles are crucial to maintaining animal groups. Inner struggles in animal groups include the combat for obtaining mating opportunities and

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 20 November 2020 doi:10.20944/preprints202010.0004.v4

killing some members for food when food is in critical shortage. Outer struggles are prevalent because animals rely on energy and materials from other organisms, like the fact that lions kill and eat antelopes for food. Inner collaboration of animal groups increases greatly the ability to win the outer struggles. Sometimes, inner collaboration can avoid inner struggles within animal groups, and this could add great fitness to the group. For example, it has been observed that several male lions collaborated closely to defeat an old lion king, and they shared the mating opportunities, and collectively fought against invaders [47]. These male lions could have no mating opportunities without the inner collaboration.

Scenarios of oppression (a kind of struggles) widely exist in the same group of lions, monkeys, mice, and humans, particularly when there is a significant difference in power among individuals. Meanwhile, scenarios of anti-oppression also widely exist in these groups. Anti-oppression events usually lead to the failed side being expelled or killed. The peace and collaboration within animal groups are thus interrupted with these anti-oppression events. Sometimes oppression is too risky and costly, particularly when the oppressed individuals become powerful. This explains the decline of oppression in human society in recent centuries with the ending of most feudal societies and colonial rulings, because the oppressed people have become more powerful. Decline in oppression is important for humans to collaborate to obtain more energy and materials for the development of human society.

Animals rely on movement for their existence and making contribution to their groups, and they also rely on changes to adapt to the changing environment. These two aspects highlight the importance of freedom. On the other side, almost all members within animal groups should obey some rules, which is fundamental for fitness of animal groups. For example, lion kings should take their responsibility to fight against invaders, and worker bees should work diligently all days for their groups, and drivers should obey traffic rules. Similarly, molecules should obey some rules with some freedom in cells, and cells should obey some rules with some freedom in multicellular organisms. Therefore, besides in eusocial or presocial animal groups, obeying rules with balanced freedom is embodied throughout the evolution of CBEs.

9. Suggestions for human society

Evolutionary views have influenced human activities and development of human society for decades [1-5,24,46,48]. Previous evolutionary theories overestimated the phenomenon of selfishness, importance of competition, and elimination of those less fit in certain traits [1-5,24]. They underestimated the increase of hierarchy, increase of diversity, and importance of altruism and collaboration. Particularly, social Darwinism which was established on the wrong view of "survival of the fittest" in the fierce competition [1-4], has been employed to justify authoritarianism, eugenics, racism, imperialism, fascism, Nazism, and struggles between national or racial groups [49]. They thus exerted negative influence on the development of human society. Socialists had to establish separate theories, such as the cultural evolution theory, to advocate altruism and collaboration for harmonious development of human society [50,51].

In contrast, the CBEET provides comprehensive and constructive suggestions for the development of human society. First, as per the CBEET, natural selection allows co-existence of many differences and changes if the relevant HHCBEs are of adequate fitness. This suggests that we should respect diversity in races, culture, and management systems. Second, natural selection accepts the effects of endeavor even if the effects are uninheritable. This suggests that we should work hard to increase our fitness. Third, natural selection emphasizes overall development and overall advantages, rather than a single trait. This is important for human individuals and human society in making decisions. Fourth, collaboration and altruism are critical throughout the evolution of CBEs including the development of human society. They are important to win outer struggles and avoid inner struggles. Fifth, the CBEET suggests that oppression in human society should be reduced because the oppressed humans have become more powerful than in the past. Sixth, obeying rules with balanced freedom is fundamental throughout the evolution of CBEs including development of human society. Collectively, humans should strengthen altruism and collaboration to struggle for peace, balanced freedom, and rational social norms. The CBEET hence vindicates human rights which were not proved with biological evolutionary theories previously. On the other side, human rights and social norms have been markedly strengthened through education and encouragement, demonstrating the effect of the cultural evolution which is unique in humans [51]. Therefore, the CBEET bridges biological evolution and the cultural evolution, and sheds novel insights into harmonious development of human society.

Besides meteorite impacts, super volcano eruptions, major climate changes, infectious diseases, unscientific beliefs, and rapid increase of global population [52], a leading challenge to the current human society is that automatic machines are taking away too many job opportunities, which aggravates wealth inequality. Again, as per the CBEET, collaboration, rather than the outdated strategies of invasion, looting, or oppression, is critical to solving these conundrums, which requires profound reform of various social notions and systems, particularly those greatly reducing national or international collaboration.

10. Discussion

The preliminary version of the CBEET was published in 2000 as an article and a book [1,2]. This preliminary version was deduced from the second law of thermodynamics and the assumption that the whole universe is an isolated system, without association with the thermodynamic features on the Earth. It was hence relatively abstract and obscure.

Natural selection, mutation, genetic drift, and competition were claimed to be the driving force of evolution [3-5,20,28,31]. These “driving forces” are not directly related to energy, and they are largely mechanisms or processes of evolution. The role of energy in biological evolution was highlighted previously [53,54], but energy was not associated with the driving force of evolution.

Here the driving force of evolution from thermodynamics provides energy for the evolution of CBEs. Moreover, all the three progressive mechanisms of evolution, including natural selection, are derived from the driving force of evolution (**Figure 1**). Therefore, the driving force of evolution plays the first leading role in evolution, although natural selection functions extensively in evolution and remains a leading role in evolution.

Evolution leads to increase of order in biology (**Figure 1**). This seems contrary to the second law of thermodynamics leading to increase of entropy which represents chaos in physics

[17,18,55]. Scientists assumed that organisms are systems with low entropy, and organisms keep low entropy through absorbing low-entropy matter and discharging high-entropy matter, and hence the notion of "negative entropy" was established [55]. We believe that this notion is wrong in this field (see **Supplementary File**), because many orderly systems, including animals and flying planes, have high entropy, and thus order should not be hooked with low entropy. For example, live dogs are warm and moving systems with many microstates, and they have hence high entropy, compared with their dead forms, or compared with perfect crystals at absolute zero which have the lowest entropy and the highest order in physics, as per the definitions of entropy [17,18]. The order in biology of a dog declines, and the order in physics of the same dog increases, when the dog is dying in the snow with heat being lost from the body, also as per the definitions of entropy [17,18]. Moreover, order in biology is established through billions of years' evolution, rather than a short-time effect of negative entropy. The CBEET was deduced herein using laws of thermodynamics without the notion of negative entropy.

11. Conclusions

We deduce the driving force of evolution from thermodynamics, and deduce three progressive mechanisms from the driving force. We hence establish the evolutionary theory CBEET which reinterprets the major aspects of evolution and provides novel explanations for natural selection, origin of life, macroevolution, speciation, and evolutionary tempos.

In one sentence, the CBEET can be expressed as "Evolution is driven hierarchy-wise by thermodynamics and favors fitness and diversity". It demonstrates that altruism, collaboration, and obeying rules with balanced freedom are important throughout the CBE evolution. It refutes several erroneous views including negative entropy and survival of the fittest. It integrates with research advances in multiple disciplines.

The CBEET suggests that human society should respect diversity, emphasize endeavor and overall development, strengthen collaboration to struggle against multiple challenges jeopardizing human society, and strengthen collaboration to struggle for peace, balanced freedom, and rational social norms. The CBEET hence links up laws of physics, evolution in biology, and harmonious development of human society.

Funding: This research has not been supported by any funds.

Acknowledgments: The author is grateful to Meng Yang and Jiwang Chen for providing valuable comments.

Conflicts of Interest: The author declares no conflict of interest.

References

1. Chen JM. A new evolutionary theory deduced mathematically from entropy amplification. Chin Sci Bul. 2000;45(1):91–96. https://doi.org/10.1007/BF02884912

2. Chen JM, Chen JW. Root of science: the driving force and mechanisms of the extensive evolution. Beijing, China: Science Press, 2000.
3. Futuyma DJ, Kirkpatrick M. Evolution. 4th ed. Sunderland, UK: Sinauer Press, 2017.
4. Huneman P, Walsh DM. Challenging the Modern Synthesis: adaptation, development, and inheritance. Oxford, UK: Oxford University Press, 2017.
5. Preiner M, Asche S, Becker S, et al. The future of origin of life research: bridging decades-old divisions. Life (Basel). 2020;10(3):20. http://doi.org/10.3390/life10030020
6. Pagel M. Natural selection 150 years on. Nature. 2009;457:808–811. https://doi.org/10.1038/nature07889
7. d'Ischia M, Manini P, Moracci M, et al. Astrochemistry and astrobiology: materials science in wonderland? Int J Mol Sci. 2019;20(17):4079. http://doi.org/10.3390/ijms20174079
8. Orgel L. In the beginning. Nature. 2006;439(7079):915–915. https://doi.org/10.1038/439915a
9. Fitzgerald DM, Rosenberg SM. What is mutation? A chapter in the series: How microbes “jeopardize” the modern synthesis. PLoS Genet. 2019;15(4): e1007995. https://doi.org/10.1371/journal.pgen.1007995
10. Koonin EV. Darwinian evolution in the light of genomics. Nucleic Acids Res. 2009;37(4):1011–1034. http://doi.org/10.1093/nar/gkp089
11. Dickins TE, Rahman Q. The extended evolutionary synthesis and the role of soft inheritance in evolution. Proc Biol Sci. 2012;279(1740): 2913–2921. http://doi.org/10.1098/rspb.2012.0273
12. Casillas S, Barbadilla A. Molecular population genetics. Genetics. 2017;205(3):1003–1035. https://doi.org/10.1534/genetics.116.196493
13. Walker SI. Origins of life: a problem for physics, a key issues review. Rep Prog Phys. 2017;80(9):092601. https://doi.org/10.1088/1361-6633/aa7804
14. Seager S. Exoplanet habitability. Science. 2013;340(577):577–581. http://doi.org/10.1126/science.1232226
15. Dodd MS, Papineau D, Grenne T, et al. Evidence for early life in earth's oldest hydrothermal vent precipitates. Nature. 2017;543(7643): 60–64. http://doi.org/10.1038/nature21377. PMID 28252057.
16. Proskurowski G, Lilley MD, Seewald JS, et al. Abiogenic hydrocarbon production at lost city hydrothermal field. Science. 2008;319(5863):604–607. http://doi.org/10.1126/science.1151194.
17. DeVoe H. Thermodynamics and chemistry. 2nd Edition. Version 10. http://www2.chem.umd.edu/thermobook/v10-screen.pdf. Accessed on Sep. 20, 2020.
18. Borgnakke C, Sonntag RE. Fundamentals of Thermodynamics. 8th edition. Hoboken, USA: John Wiley & Sons, 2013.
19. Carbon. https://en.wikipedia.org/wiki/Carbon. Accessed on Sep. 20, 2020.
20. Benton MJ. The Red Queen and the Court Jester: species diversity and the role of biotic and abiotic factors through time. Science. 2009;323(5915):728–732. http://doi.org/10.1126/science.1157719
21. Lynch M. The frailty of adaptive hypotheses for the origins of organismal complexity. Proc Natl Acad Sci U S A. 2007;104(Suppl 1):8597–8604. http://doi.org/10.1073/pnas.0702207104
22. Rohde RA, Muller RA. Cycles in fossil diversity. Nature. 2005;434(7030):208–210. http://doi.org/10.1038/nature03339

23. Percival LME, Ruhl M, Hesselbo SP, et al. Mercury evidence for pulsed volcanism during the end-Triassic mass extinction. Proc Natl Acad Sci U S A. 2017;114(30):7929–7934. http://doi.org/10.1073/pnas.1705378114
24. Fields BD, Melott AL, Ellis J, et al. Supernova triggers for end-Devonian extinctions. Proc Natl Acad Sci U S A. 2020;117(35):21008–21010. http://doi.org/10.1073/pnas.2013774117
25. Bader J, Jungclaus J, Krivova N, et al. Global temperature modes shed light on the Holocene temperature conundrum. Nat Commun. 2020;11:4726. https://doi.org/10.1038/s41467-020-18478-6
26. McGee MD, Borstein SR, Meier JI, et al. The ecological and genomic basis of explosive adaptive radiation. Nature. 2020. https://doi.org/10.1038/s41586-020-2652-7
27. Hunt T. Reconsidering the logical structure of the theory of natural selection. Commun Integr Biol. 2014;7(6):e972848. https://doi.org/10.4161/19420889.2014.972848
28. Nei M. Mutation-driven evolution. Oxford, UK: Oxford University Press, 2013.
29. Olivieri DN, Mirete-Bachiller S, Gambón-Deza F. Insights into the evolution of IG genes in Amphibians and Reptiles. Dev Comp Immunol. 2020: 103868. https://doi.org/10.1016/j.dci.2020.103868. Epub ahead of print.
30. Chen J, Sun Y. Variation in the analysis of positively selected sites using nonsynonymous/synonymous rate ratios: an example using influenza virus. PLoS One. 2011;6(5):e19996. http://doi.org/10.1371/journal.pone.0019996.
31. Hershberg R, Petrov DA. Selection on codon bias. Annu Rev Genet. 2008;42(1):287–299. http://doi.org/10.1146/annurev.genet.42.110807.091442
32. Levy E, Erba E, Robinson C, et al. Assembly reflects evolution of protein complexes. Nature. 2008;453:1262–1265. https://doi.org/10.1038/nature06942
33. Follmann H, Brownson C. Darwin's warm little pond revisited: from molecules to the origin of life. Naturwissenschaften. 2009;96(11):1265–1292. http://doi.org/10.1007/s00114-009-0602-1.
34. Subramanian H, Brown J, Gatenby R. Prebiotic competition and evolution in self-replicating polynucleotides can explain the properties of DNA/RNA in modern living systems. BMC Evol Biol. 2020;20(1):75. http://doi.org/10.1186/s12862-020-01641-4
35. Lazcano A. Alexandr I. Oparin and the origin of life: A historical reassessment of the heterotrophic theory. J Mol Evol. 2016;83(5-6):214-222. http://doi.org/10.1007/s00239-016-9773-5.
36. Patel BH, Percivalle C, Ritson DJ, et al. Common origins of RNA, protein and lipid precursors in a cyanosulfidic protometabolism. Nat Chem. 2015;7(4): 301–307. http://doi.org/10.1038/nchem.2202
37. Kauffman SA. Approaches to the origin of life on the Earth. Life (Basel). 2011;1(1):34–48. http://doi.org/10.3390/life1010034
38. Robertson MP, Joyce GF. The origins of the RNA world. Cold Spring Harb Perspect Biol. 2012;4(5): a003608. http://doi.org/10.1101/cshperspect.a003608
39. Ermakova GV, Kucheryavyy AV, Zaraisky AG, et al. Discovery of four Noggin genes in lampreys suggests two rounds of ancient genome duplication. Commun Biol. 2020;3:501. https://doi.org/10.1038/s42003-020-01234-3

40. Lin Z, Chen L, Chen X, et al. Biological adaptations in the Arctic cervid, the reindeer (Rangifer tarandus). Science. 2019;364(6446):eaav6312. http://doi.org/10.1126/science.aav6312
41. Torres-Garcia S, Yaseen I, Shukla M, et al. Epigenetic gene silencing by heterochromatin primes fungal resistance. Nature. 2020;585:453–458. https://doi.org/10.1038/s41586-020-2706-x
42. McGee MD, Borstein SR, Meier JI, et al. The ecological and genomic basis of explosive adaptive radiation. Nature (2020). https://doi.org/10.1038/s41586-020-2652-7. Epub ahead of print.
43. Bird CE, Fernandez-Silva I, Skillings DJ, et al. Sympatric Speciation in the Post “Modern Synthesis” Era of Evolutionary Biology. Evol Biol. 2012;39:158–180. https://doi.org/10.1007/s11692-012-9183-6
44. Fehr E, Fischbacher U. The nature of human altruism. Nature. 2003;425:785–791. https://doi.org/10.1038/nature02043
45. Styrsky JD, Eubanks MD. Ecological consequences of interactions between ants and honeydew-producing insects. Proc Biol Sci. 2007;274(1607):151–164. http://doi.org/10.1098/rspb.2006.3701
46. Nowak M, Tarnita C, Wilson E. The evolution of eusociality. Nature. 2010;466:1057–1062. https://doi.org/10.1038/nature09205
47. Mapogo lion coalition. https://en.wikipedia.org/wiki/Mapogo_lion_coalition. Accessed on Sep. 20, 2020.
48. Ferriere, R, Michod, R. Inclusive fitness in evolution. Nature. 2011;471:E6–E8. https://doi.org/10.1038/nature09834
49. Rudman LA, Saud LH. Justifying Social Inequalities: The role of social Darwinism. Pers Soc Psychol B. 2020;46(7):1139–1155. https://doi.org/10.1177/0146167219896924
50. Carroll SP, Jørgensen PS, Kinnison MT, et al. Applying evolutionary biology to address global challenges. Science. 2014;346(6207):1245993. https://doi.org/10.1126/science.1245993.
51. Henrich J. The secret of our success: how culture is driving human evolution, domesticating our species, and making us smarter. Princeton, UK: Princeton University Press, 2015.
52. Lufkin B. 50 Grand Challenges for the 21st Century. BBC. 2017. https://www.bbc.com/future/article/20170331-50-grand-challenges-for-the-21st-century. Accessed on Sep. 20, 2020.
53. Martin WF, Sousa FL, Lane N. Energy at life's origin. Science. 2014;344:1092–1093. https://doi.org/10.1126/science.1251653
54. Sousa FL, Thiergart T, Landan G, et al. Early bioenergetic evolution. Philos Trans R Soc Lond B Biol Sci. 2013;368(1622):20130088. http://doi.org/10.1098/rstb.2013.0088
55. Schrödinger E. What is life – the physical aspect of the living cell. Cambridge, UK: Cambridge University Press, 1944.