doi:10.20944/preprints202010.0004.v10

The Carbon-Based Evolutionary Theory (CBET)

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Abstract

To establish a comprehensive and comprehensible evolutionary theory, and to use this theory to bridge physics, biology, and social sciences, we employ the concept carbon-based entities (CBEs), which include methane, glucose, proteins, organisms, and other entities chemically containing carbon atoms. We deduce the steps, driving forces, and mechanisms of evolution of CBEs through integration of geology, physics, chemistry, and biology. We hence establish the Carbon-Based Evolutionary Theory (CBET), which suggests that evolution is the increase in the amount, diversity, and fitness of higher-hierarchy CBEs under natural selection and driven by the organic synthesis tendency on the Earth from the thermodynamic features of the Earth. It provides better explanations for various evolutionary issues and social issues (e.g. life origin, natural selection, neutral mutation, diversity importance, and altruism) than previous theories. It refutes some incorrect views (e.g. negative entropy) in thermodynamics on evolution. The CBET could have great significance in various sciences.

Keywords

carbon-based entity; driving force; energy; entropy; evolution; fitness; mechanism; natural selection; thermodynamics; theory

1. Introduction

Evolution is a hottest topic of natural sciences and social sciences. Many evolutionary theories have been proposed, and the mainstream evolutionary theories are Darwin's theory emerging in the 19th century and the Modern Synthesis emerging in the 20th century [1-3]. Darwin's theory elucidated the importance of natural selection, and the Modern Synthesis established the genetic basis of natural selection. The definition of natural selection in Darwin's theory, survival of the fittest, is literally confusing because many individuals who are not the fittest can survive and replicate [1-3]. The Modern Synthesis reinterpreted natural selection as gradual changes in gene frequencies of populations because those individuals carrying adaptive mutations are more reproductively successful [1-3].

For evolution, geology provides the environment and fossil evidence, physics the temporal direction, chemistry the molecular mechanism, and biology the genetic basis [2]. Therefore, a comprehensive evolutionary theory should be based on integration of these four disciplines, but previous evolutionary theories are largely based on one or two of these disciplines [3]. Therefore, they are incomplete and difficult to explain life origin and some events of macroevolution (e.g. some unicellular organisms evolved to multicellular organisms, and some ectotherm animals evolved to warm-blooded animals) [1-5,10,18-21]. Moreover, these theories cannot integrate with some challenges identified in recent decades: evolution of many species showed the punctuated equilibrium tempo with little change in long geological periods and significant changes in short geological periods; many genetic mutations are neutral or even harmful in natural selection; some mutations occur not randomly; some acquired epigenetic changes are heritable and important for adaption of organisms [1-15].

Here we deduce the Carbon-Based Evolutionary Theory (CBET) through integration of geology, physics, chemistry, and biology (**Figure 1**). We aim to establish a comprehensive and comprehensible evolutionary theory, and use this theory to bridge physics, biology, and social sciences. The major role in the CBET is carbon-based entities (CBEs), which include methane, amino acids, proteins, nucleic acids, lipids, organisms, and other entities chemically containing carbon atoms [22]. CBEs are suitable to be the leading actor in a scientific and comprehensive evolutionary theory, because they are the leading actor of the evolution, which likely started over 4.0 billion years ago (**Ga**) on the Earth covering life origin and life evolution. CBEs are more readable, concrete, and specific than quanta, molecules, microscopic particles, systems, matter, and more inclusive than organic compounds, carbohydrates, organisms, and genes, for exploring evolutionary issues [23-28].

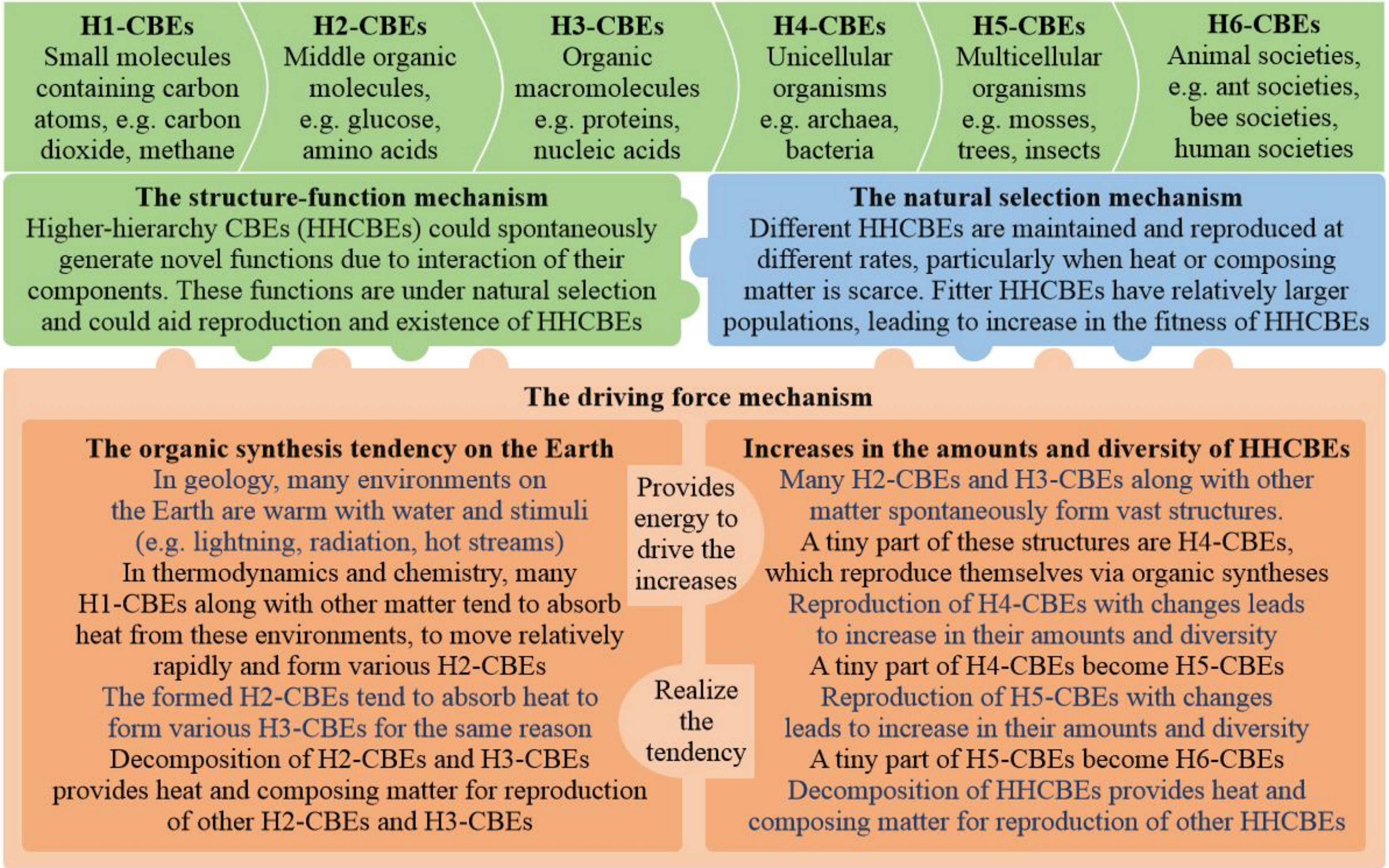

Figure 1. The steps, driving force, and mechanisms of evolution of carbon-based entities (CBEs) as per the CBET. Previous mainstream evolutionary theories largely correspond to the blue part of the CBET.

2. Hierarchies and functions of CBEs

We classify CBEs into six hierarchies (H1 – H6). H1-CBEs are some small molecules containing carbon atoms (e.g. carbon dioxide, methane, and ethanol). H2-CBEs are middle-sized organic molecules (e.g. amino acids, nucleotides, and glucose). H3-CBEs are organic macromolecules (e.g. proteins, nucleic acids, and lipids). H4-CBEs are unicellular organisms (e.g. archaea, bacteria, protozoa). H5-CBEs are multicellular organisms (e.g. grasses, trees, fishes, tigers). H6-CBEs are animal societies (e.g. ant societies, bee societies, and human societies) established on close collaboration of individuals of the same animal species. Higher-hierarchy CBEs (HHCBEs) and lower-hierarchy CBEs (LHCBEs) are defined through comparing their hierarchies. Sometimes HHCBEs mean H3-CBEs, H4-CBEs, H5-CBEs, and H6-CBEs, and LHCBEs mean H1-CBEs or H1-CBEs and H2-CBEs.

Noteworthily, there are no clear lines separating these hierarchies. For example, some peptides are between H2-CBEs and H3-CBEs, and viruses are between H3-CBEs and H4-CBEs, and lion groups are between H5-CBEs and H6-CBEs.

HHCBEs spontaneously obtain some complicated functions due to interaction of their components, or to say, due to their complicated structures [2]. For example, although no amino acids emit fluorescence, when green fluorescence protein is formed by amino acids, it obtains spontaneously the function of emitting green fluorescence, due to interaction of amino acids. Likewise, although no cells can fly, when a bird is formed by many cells, it can fly spontaneously due to interaction of its cells.

3. The primary driving force and major steps of evolution

3.1 Two contrary thermodynamic tendencies on the Earth

In geology, the Earth's surface has vast warm environments with water and stimuli (e.g. lightning, radiation, hot streams). As a rare habitable planet in astronomy, the Earth receives temperate sunlight for billions of years [14]. Meanwhile, many sites on the Earth, particularly at hydrothermal vents, have emitted geothermal energy for long periods [16,17]. The Earth has much liquid water and the atmosphere to make these warm environments more temperate, more widespread and last longer through winds, rains, and evaporation.

In physics, as per the second law of thermodynamics, namely, heat can spontaneously flow from a hotter body to a colder body, and cannot spontaneously flow from a colder body to a hotter body (see **Supplementary File**) [20,21], many molecules have the tendency to absorb heat from vast warm environments on the Earth, to move relatively rapidly.

 doi:10.20944/preprints202010.0004.v10

In chemistry, many H1-CBEs (e.g. CO_2 and CH_4) along with some other small molecules (e.g. H_2S, H_2O, NH_3) on the Earth have the tendency, after absorbing heat from vast warm environments on the Earth and moving more rapidly, to form H2-CBEs (e.g. amino acids, nucleotides, glucose), particularly with a stimulus (e.g. lightning, radiation, or a hot stream). The formed H2-CBEs along with some other small molecules also have the tendency, after absorbing heat from vast warm environments on the Earth and moving more rapidly, to form H3-CBEs (e.g. proteins, nucleic acids, lipids, polysaccharides), particularly with a stimulus [22]. Altogether, many molecules on the Earth have the tendency to absorb heat from vast warm environments on the Earth to form organic molecules. As detailed below, this organic synthesis tendency (OST) on the Earth drives evolution of CBEs.

In chemistry, many organic molecules on the Earth also have the tendency to decompose (**Figure 2**), to release heat to the environment, after they have been activated by relatively strong stimuli (e.g. a fire), because all CBEs are formed with relatively fragile bonds [2].

In chemistry, organic molecules can be decomposed only after they have been formed and many organic molecules can be preserved for a relatively long time. Like many organic synthesis reactions in laboratories, the overall OST could outrun the overall organic decomposition tendency on the early Earth with too many H1-CBEs, too few H2-CBEs, and too few H3-CBEs. Later, with the decline of H1-CBEs and the increase of H2-CBEs and H3-CBEs on the Earth, these two contrary tendencies could maintain a relative balance on the Earth (**Figure 2**).

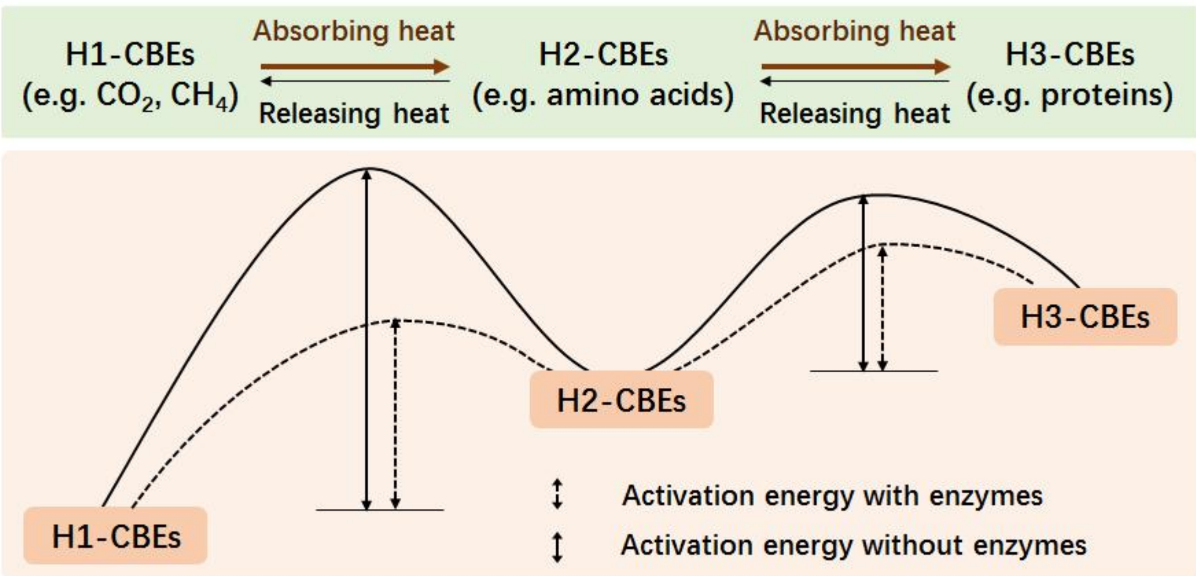

Figure 2. The tendencies of organic synthesis and decomposition on the Earth. The organic reactions require activation energy which can be reduced by enzymes.

3.2 Accumulation of enzymes due to the OST

In chemistry, the above natural organic synthesis or decomposition reactions are very slow if they are not aided by enzymes, because they require relatively high activation energy (**Figure 2**) [2]. Sometimes lightning, radiation, and other stimuli can provide activation energy for these reactions. Moreover, these reactions can be accelerated by relevant enzymes which can reduce significantly the required activation energy (**Figure 2**). Some H3-CBEs synthesized through the above natural organic syntheses are enzymes of some organic synthesis or decomposition reactions. These H3-CBEs can accelerate the above natural organic synthesis or decomposition reactions. Noteworthily, each enzyme usually can catalyze only certain reactions, and all enzymes only accelerate organic reactions, not determine the general directions (namely synthesis or decomposition) of organic reactions, which are determined by thermodynamics [2].

3.3 Emergence and development of H4-CBEs

In geology, a huge amount of various H2-CBEs and H3-CBEs could have been accumulated on the Earth through the above natural organic syntheses before life origin [29,30]. The then Earth could be fetid like the Murchison meteorite which feel to the Earth in 1969, due to relatively high concentration of various organic molecules [29,30].

These H2-CBEs and H3-CBEs along with other inorganic or organic molecules could spontaneously form a myriad of structures. Winds and water flows on the Earth could aid those CBEs and other molecules to meet and form these structures. Most of these structures could have little significance in evolution. Some of them were simple (e.g. lipid bilayer membranes and ion channels). Some others were complicated and had complicated functions, such as synthesis of proteins or nucleic acids relatively precisely using enzymes as per the direction of some sequences of nucleic acids.

Among these various structures, there could be a very complicated type of structures, namely unicellular organisms (i.e. H4-CBEs). Emergence of H4-CBEs in this way represents life origin through abiogenesis. Because H4-CBEs are very complicated in structures, their emergence possibility is very low.

The earliest H4-CBEs could be archaea emerging in warm seas 3.8 Ga [3]. H4-CBEs are composed by various H2-CBEs and H3-CBEs and some other molecules. H4-CBEs could reproduce themselves with two supports. One is the collaboration of their components in their complicated structures (see **Section 2**), which enables H4-CBEs to conduct various organic syntheses and reproduce themselves relatively precisely for multiple copies through these organic syntheses, if their environments provide them heat and composing matter. The other is the OST of their environments, which provides H4-CBEs heat and composing matter for their reproduction. H4-CBEs also meet the OST relatively efficiently, because they conduct various organic syntheses relatively efficiently using many enzymes, and their reproduction means they employ more copies of many enzymes to conduct more organic syntheses.

H4-CBEs harbor some organic molecules which constitute the genomes of H4-CBEs and provide relatively precise direction for the many enzyme-aided reactions involved in the reproduction of H4-CBEs. Without genomes, H4-CBEs could not be reproduced relatively precisely due to the inherent vast possibilities of synthesis of organic macromolecules. In biology, genomes of H4-CBEs are composed by nucleic acids whose sequences encode much information for relatively precise direction of various organic syntheses in H4-CBEs.

3.4 Emergence and development of H5-CBEs

Although H4-CBEs are reproduced relatively precisely, changes in their offspring are also unavoidable, mainly because reproduction of their genomes cannot be exactly precise in chemistry. Among the vast changes of H4-CBEs, some rare changes could transfer H4-CBEs to H5-CBEs (i.e. multicellular organisms). In geology, H5-CBEs emerged about 2.2 Ga [3], which means that it took over one billion years for H4-CBEs to evolve into H5-CBEs. H5-CBEs usually require more temperate environments compared to H4-CBEs. For example, many H4-CBEs but no known H5-CBEs can live at a temperature over 100 °C. Likewise, reproduction of many H5-CBEs (e.g. trees and tigers) is supported thermodynamically by the OST of their environments and functionally by the collaboration inside their complicated structures, including the collaboration among their cells and the collaboration among molecules in the cells. Like H4-CBEs, changes in the genomes of the offspring of H5-CBEs are unavoidable. This leads to increase in the diversity of organisms.

3.5 Emergence and development of animals and H6-CBEs

All the HHCBEs from H3-CBEs to H5-CBEs accumulated through the above natural organic syntheses decompose and release heat some time after their formation, as per their chemical features (see **Section 3.1**). Their decomposition increases the OST of the relevant environments, because it provides LHCBEs and temperate heat for natural organic syntheses of other HHCBEs. This supports the emergence of decomposers (e.g. fungi), consumers (e.g. animals), and parasites (e.g. ascarid) in ecosystems. These roles in ecosystems increase the diversity of organisms.

Animals should obtain enough food, which contains heat and matter required for their existence and reproduction, from other living or dead organisms. They should also protect themselves. These functions are realized through various strategies (see **Section 2**). Among these strategies, one is that many animal individuals of the same species collaborate closely with each other and form animal societies (i.e. H6-CBEs), which include societies of bees, ants, humans, and thousands of other species [27,28]. Usually long geological periods are required for emergence of novel H6-CBEs because they are more complicated in structure than their H5-CBE ancestors. Likewise, these animal societies (e.g. ant societies) could maintain their existence via reproduction of some individuals in the societies, with the support from the OST of their environments and the collaboration in their complicated structures, including the collaboration among the individuals in the societies.

3.6 The primary driving force of evolution

The above increases in the amount and the diversity of HHCBEs, including accumulation of organic molecules, life origin, organism reproduction, and increase in roles of ecosystems, are based on various organic syntheses. The OST from the thermodynamic features of the outside environment provides heat or energy to drive the above increases in the amount and the diversity of HHCBEs. Therefore, the OST is the primary driving force of the increases in the amount and the diversity of HHCBEs, namely evolution of CBEs. With this driving force from the outside environment, the HHCBEs can be formed and maintained for some time due to their inner structures.

During the early history of the Earth, the amount and the diversity of HHCBEs including organisms on the Earth were generally increasing [23]. However, meteorite impacts, huge volcano eruptions, long-term glacial periods, and other catastrophes can destroy vast warm environments on the Earth and structures of many organisms [24-26]. Consequently, the amount and the diversity of organisms could decline greatly, sometimes leading to mass extinctions [24-26]. Loss of ecological equilibrium can also lead to decline in the amount and the diversity of organisms in some ecosystems for some time [2,3].

Water is critical for evolution of CBEs. Besides making warm environments on the Earth more temperate, more widespread and last longer, water participates in various organic syntheses as an important substrate and the reaction environment. Water flows facilitate various molecules to meet for organic syntheses. Water is also important to maintain the structures and functions of many organic molecules and HHCBEs.

4. Three mechanisms of evolution

There are three interactive mechanisms of evolution. The first is the driving force mechanism mentioned in **Section 3.6**, which leads to increase in the hierarchy and the structural complexity of CBEs, increase in the amount and the diversity of HHCBEs, and increase in the role of ecosystems, as deduced above (**Figure 1**).

The second is the structure-function mechanism, which represents that CBEs with increased hierarchy and structural complexity spontaneously obtain some complicated functions (e.g. reproduction, non-random mutation, and sexual reproduction), due to interaction inside HHCBEs, as mentioned in **Section 2**. All these functions should be under natural selection. For example, non-random mutations in many microbial genomes and mammalian immunoglobulin genes [9,15] facilitate to generate advantageous mutations and avoid disadvantageous mutations. Sexual reproduction facilitates to generate numerous mutants, which are useful for organisms to fit different environments, through recombination of genomic sequences. This mutation strategy is usually less risky than nucleotide substitutions, because the recombined genomic sequences have been tested by long-term history [2,3]. Some theories ascribed the complicated function of reproduction of primitive cells to some special molecules with autocatalysis (e.g. RNA) [31], while the CBET ascribed this function to collaboration of various molecules in primitive cells.

The third is natural selection, which is a tautology. Namely, fit HHCBEs survive, and those HHCBEs that have survived are fit HHCBEs; fitter HHCBEs have larger populations, and those HHCBEs having larger populations are fitter HHCBEs. Previously natural selection was criticized due to its tautology [32]. We think this tautology cannot refute natural selection, like the fact that the champion is the one who runs the fastest, and the one who runs the fastest is the champion, and there must be a champion if there is a race. Natural selection must exist if HHCBEs are repeatedly reproduced, because no mechanism makes all HHCBEs formed and maintained at the same rate. Therefore, long-term repeated formation of HHCBEs and its primary driving force from thermodynamics are the prerequisites of natural selection.

The results of natural selection are changes in the amount of different HHCBEs over time, namely that some HHCBEs have increased their amounts, while some other HHCBEs have reduced their amounts. These changes are determined by these four aspects: different formation rates of HHCBEs with enough heat and composing matter, different decomposition rates or longevity of HHCBEs, different ability of HHCBEs to compete for heat when heat is in short, different ability of HHCBEs to compete for composing matter when composing matter is in short. These four aspects co-determine the overall fitness of an HHCBE.

With the increase in the amount and the diversity of organisms, resources of heat or composing matter become inadequate, and competitions among organisms for heat and composing matter become fierce. Hence some mutants reduce their amounts and even become extinct. Only fit mutants or those mutants that have won the competitions can survive, and fitter mutants shall have relatively larger populations. This leads to increase in the fitness of organisms. The CBET integrates with Darwin's theory and the Modern Synthesis in this respect. Whether an organism is fit is determined by the organism and its environment (e.g. an organism of great fitness in forests can be unfit in deserts).

Theoretically, through natural selection, the efficiency of the natural organic synthesis on the Earth could increase over time if the environment keeps relatively constant, because natural selection means that fitter HHCBEs shall have relatively larger populations, which should be supported by more efficient organic synthesis. The sequential emergence and increases of H3-CBEs, H4-CBEs, H5-CBEs, and H6-CBEs through evolution, as given in **Section 3**, all could enhance the efficiency of natural organic synthesis, because they could enable the Earth to conduct more and more organic synthesis using more and more enzymes.

Natural selection, mutation, genetic drift, or competition was claimed to be the driving force of evolution [3-5,21,33,34]. These actions are not directly based on energy, and they are largely mechanisms or processes of evolution, so they are not the primary driving force of evolution. On the other side, natural selection can directly shape many traits of organisms, so it can be the secondary driving force of evolution. Although energy in biological evolution was highlighted previously [35,36], it has not been linked to the driving force of evolution.

Collaboration with altruism (altruism is a special type of collaboration supporting the production and functions of other entities), obeying rules, and restricting freedom are important throughout evolution. Otherwise, HHCBEs could not be fit HHCBEs or survive. For example, many small molecules spontaneously collaborate with each other, obey some rules, and sacrifice their freedom to form organic molecules, and many organic molecules inside cells spontaneously collaborate with each other, obey some rules, and sacrifice their freedom to support the replication and functions of nucleic acids, and many immune cells in multicellular organisms spontaneously collaborate with each other, obey some rules, and sacrifice their freedom to support other cells. Many individuals in animal societies spontaneously collaborate with each other and sacrifice their freedom to support the existence of other individuals.

On the other side, freedom of CBEs increases along with the increase in their hierarchies. For example, many atoms can hardly move in large molecules, while many molecules can move relatively freely inside cells. Many cells cannot move freely in multicellular organisms, while many animal individuals can move relatively freely in certain areas. Moreover, the CBET suggests that both obeying rules and making proper changes are essential for fitting various environments. In these two senses, freedom should be properly extended.

5. Further explanations of natural selection in the CBET

Natural selection in the CBET is different from natural selection in Darwin's theory and the Modern Synthesis in the following aspects, although they all represent the same natural process or mechanism leading to increase of fitness.

First, natural selection in the CBET applies to inanimate HHCBEs and organisms (**Figure 1**), while natural selection in previous theories is largely restricted to organisms.

Second, natural selection was expressed as "survival of the fittest" in Darwin's theory, and "gradual replacement of populations with those carrying advantageous mutations" in the Modern Synthesis [1-3], while natural selection is expressed as "survival of the fit" in the CBET, as per its tautology (i.e. fit HHCBEs survive and those HHCBEs that have survived are fit HHCBEs). "Survival of the fit" includes elimination of the fitter HHCBEs if they are unfit in harsh environments [24-26], and survival of the HHCBEs less fit if they are fit in suitable environments (this was largely neglected by previous evolutionary theories), and the tendency that those fitter HHCBEs shall have relatively larger populations, which leads to increase in the fitness.

Third, natural selection in previous theories usually emphasizes fitness in a single aspect, while natural selection in the CBET highlights the overall fitness. Those HHCBEs carrying changes advantageous, neutral or even harmful in fitness, such as those changes leading to life origin, multicellular organisms, warm-blooded animals, thalassemia, and diabetes can all survive and replicate, if they have adequate overall fitness in suitable environments. This facilitates increase in the biological diversity, and further explains some macroevolution events. For example, it was possible that amphibians evolved from fish not because amphibians have more fitness than fish, but because amphibians and fish both have adequate fitness in their suitable environments [32]. This is also consistent with research advances which suggest that many genomic changes are neutral without increase in the fitness, and many organisms carry disadvantageous traits and harmful mutations (e.g. those lead to thalassemia and diabetes) [3-5,37]. This suggests a novel mechanism of sympatric speciation:

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different mutants of a species carrying various combinations of traits can all replicate efficiently in the same ecological niche of the same area, if they all have adequate overall fitness, particularly when these traits need optimization and the mutants have relatively small populations. For example, antelopes are less strong than buffaloes to fight against carnivores, but they run fast and have other advantages, making their overall fitness adequate, and could hence speciate in the same ecological niche of the same area with buffaloes. Previously, only the mechanism for sympatric speciation targeting different ecological niches of the same area has been proposed, as different ecological niches exert different selection pressures [3].

Fourth, as per previous theories a biological trait is usually assumed to be advantageous in natural selection, while in the CBET a biological trait may be neutral, advantageous, or disadvantageous in natural selection in general, as explained above. Moreover, a biological trait may be advantageous in some aspects and disadvantageous in some other aspects (e.g. long necks of giraffes could be useful for finding predators, but harmful to bones and hearts; warm-blooded animals could be fitter than ectotherm animals in warm environments, but less fit in surviving cold environments), so this trait can be simultaneously under both positive selection (namely that natural selection promotes those changes which add fitness) in some aspects and negative selection (namely that natural selection inhibits those changes which reduce fitness) in some other aspects. As given in **Figure 3**, co-action of positive selection and negative selection on the same trait provides a comprehensive explanation for the widespread evolutionary tempo of punctuated equilibrium.

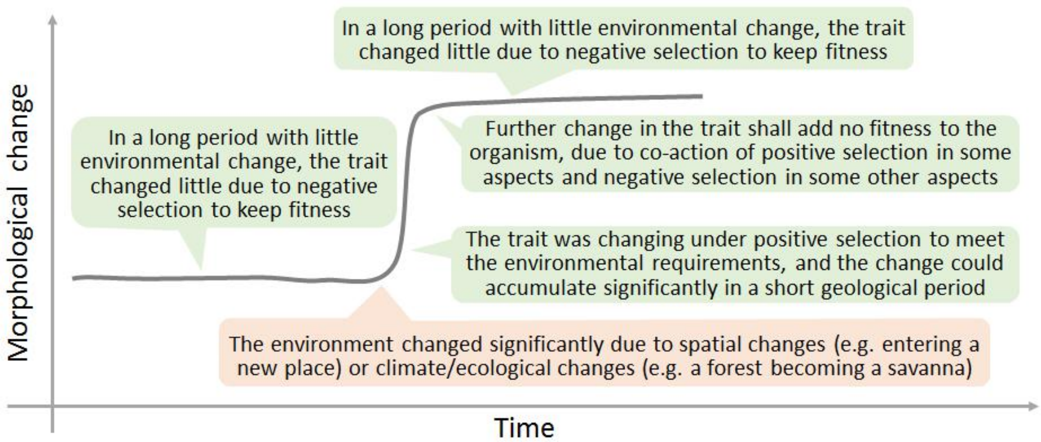

Figure 3. Co-action of positive selection and negative selection on the same trait leading to the punctuated equilibrium tempo.

 doi:10.20944/preprints202010.0004.v10

Fifth, the targets of natural selection in previous theories were claimed to be individuals, populations, or genes [34,38], while all genomic sites, all traits, and all hierarchies are claimed to be under natural selection in the CBET. This is because natural selection "selects" organisms as per their overall fitness, which is influenced by all genomic sites, all traits, and all hierarchies. 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 [38].

Sixth, previous definitions of natural selection targeted only inheritable changes, while in the CBET, genetic mutations, epigenetic changes, and uninheritable changes all influence the overall fitness of HHCBEs, and they are thus all under natural selection. For example, vaccination makes many animals survive viral infections and pass the relevant natural selection. This suggests that education, vaccination and other efforts, although not inheritable, can add fitness of humans and hence should be highlighted.

6. Influence of evolution on evolution

Evolution provides the bases for the next step of evolution. Some H2-CBEs evolved from H1-CBEs, such as adenosine triphosphate, could hold and transfer heat for organic syntheses involved in the later evolutionary steps. Some H3-CBEs evolved from H2-CBEs are enzymes which facilitate various organic syntheses involved in later evolutionary steps. Increase in the amount and the diversity of organisms (H4-CBEs and H5-CBEs) due to evolution provides temperate heat and composing matter for development of fungi and animals.

Evolution can change the environment and provide novel selection pressures, e.g. the pressure on anaerobes due to increase of oxygen concentration in the air caused by biological photosynthesis, and the pressure on herbivores due to emergence of carnivores [3].

Evolution adds novel secondary driving forces to evolution. For example, animal selection of sexual partners (sexual selection) directly influences some traits of many animals [2,3]. Human desire for knowledge and happiness directly influences some important traits of humans. They are novel secondary driving forces of evolution.

Humans evolved from animals exert great and extensive influences on evolution, leading to extinction of many species, creation of novel variants of many species, exploration of multiple novel energy, and pollution of vast environments. Humans also synthesize a huge amount of organic molecules using inanimate systems every year.

7. Reliability of the CBET

The CBET is not built on novel laws, novel observations, or novel experiments. As detailed above, the CBET employs integration of geology, physics, chemistry, and biology using the thermodynamic features of the Earth, the simple expression of the second law of thermodynamics which is also directly applicable to evolution, the concrete leading actor throughout life origin and evolution (namely CBEs), the chemical features and reactions of CBEs leading to evolution, and some logics for complex issues. The multidisciplinary integration and the five factors used in the integration are all important for a scientific, comprehensive, and comprehensible evolutionary theory, but almost all of them were neglected by previous theories. These facts support the CBET.

All known biological reactions comply with classical laws of thermodynamics. Growth of all known organisms, and creation of various viruses and some bacteria in laboratories through genetic engineering, production of organic molecules in factories [39-41], all require thermodynamic support and involves a process that molecules absorb heat to move relatively rapidly and synthesize organic molecules. The amount and the diversity of organisms are larger in tropic forests than in tropic deserts and in cold areas, and they are usually larger in warm seasons than cold seasons. These facts support the CBET.

The CBET provides better explanations for multiple evolutionary issues, such as life origin, macroevolution events, non-random mutations, prevalent neutral or harmful mutations, sympatric speciation, punctuated equilibrium, effects of uninheritable traits on fitness, and altruism (**Table 1**). These better explanations support the CBET.

Although we believe that the major views of the CBET shown in **Figure 1** are reliable, some details of this theory should be optimized and extended. Moreover, although the CBET explains multiple evolutionary issues, it cannot explain the certainty of evolution on the Earth.

Table 1. Better explanations given by the CBET for some evolutionary issues

Issue	Previous explanation	Explanations of the CBET
The primary driving force of evolution	Natural selection, genetic drift, competition, or mutation (none of them directly involves energy)	The thermodynamic tendency of many molecules on the Earth to absorb heat from vast warm environments, to move relatively rapidly and synthesize organic molecules
Progressive mechanisms of evolution	Natural selection, sexual selection, and epigenetic changes lead to increase in the fitness of organisms	The primary driving force increases the hierarchy and diversity of carbon-based entities (CBEs); higher-hierarchy CBEs (HHCBEs) obtain spontaneously some complicated functions under natural selection; natural selection increases in the fitness of HHCBEs

Natural selection	Gradual replacement of populations with those carrying advantageous mutations; highlighting selection in a single aspect, random mutations, and inheritable changes	Fitter HHCBEs shall have relatively larger populations; highlighting neutral mutations and diversity; allowing disadvantageous traits; highlighting the overall fitness constituted by all traits; highlighting selection in various aspects, both random and non-random mutations, both inheritable and uninheritable changes
Life origin	Life origin has been explained with elusive concepts (e.g. negative entropy, dissipation systems, RNA, autocatalysis)	As given in **Figure 1**, the primary driving force and mechanisms of life origin are explained with simple concepts (e.g. carbon-based entities and organic molecules); collaboration of various molecules for life origin is highlighted
Animal and human societies	Neglecting the hierarchy of animal societies in evolution; difficult to explain some social notions	Listing the hierarchy of animal societies in evolution; revealing the evolutionary bases of various social notions important for harmonious social development
Origin of multicellular organisms	For unknown reasons as unicellular organisms could be fitter than multicellular organisms in many environments	Many niches could be better employed for organic syntheses by multicellular organisms for their reproduction; multicellular organisms could have adequate fitness even if they could be less fit than unicellular organisms
Origin of warm-blooded animals	For unknown reasons as warm-blooded animals could be less fit than ectotherm animals in many environments	Many biomaterials could be better employed for organic syntheses by warm-blooded animals for their reproduction; warm-blooded animals could have adequate fitness even if they could be less fit than ectotherm animals
Non-random, neutral, or harmful mutations	Have not provided explanations for non-random mutations and neutral or harmful mutations	Non-random mutations can be realized through the complicated structures of organisms and useful for increasing fitness. Many neutral or harmful mutations can be maintained if the overall fitness of relevant organisms is adequate
Sympatric speciation in the same niche of the same area	No mechanism was proposed for sympatric speciation in the same niche of the same area.	Various combinations of multiple traits can all constitute adequate fitness in the same niche of the same area. These combinations can be fixed particularly when these traits need optimization and the relevant mutants have small populations
The punctuated equilibrium tempo	Due to geographical isolation for elusive reasons	Due to positive selection in some aspects and negative selection in some other aspects on the same trait as per environmental changes including geographical and climate changes
Uninheritable efforts	Effects of efforts in natural selection were neglected	Effects of efforts (e.g. vaccination and education) in natural selection are highlighted
Altruism and some other traits	Altruism was explained using group selection and the hypothesis of kin selection; assuming that all traits are advantageous in natural selection	Altruism of components for the whole system is important throughout evolution; altruism of animal individuals is important for animal societies; not all traits are advantageous in natural selection; a trait may be advantageous in some aspects, but harmful in some other aspects

8. Significance of the CBET

For biology, as given in above sections, the CBET is deduced from multidisciplinary integration and reveals the driving forces and mechanisms of evolution from a panorama view. It provides better explanations for multiple evolutionary issues than previous evolutionary theories. Therefore, the CBET is more scientific and comprehensive than previous theories.

For social sciences, the CBET reveals the evolutionary basis of various important notions for harmonious development of human society. Previous evolutionary theories highlight selfishness, competition, and elimination of those less fit in certain traits [1-5,24]. These prejudiced notions have been employed to justify authoritarianism, racism, fascism, and Nazism [42]. The CBET not only emphasizes selfishness, fitness, competition, and genetic features in natural selection, but also emphasizes respecting diversity, collaborating with altruism, obeying rules, extending freedom, protecting environments, and highlighting inheritable efforts. These notions of the CBET are all important for harmonious development of human society. The CBET suggests that humans originated from animals through billion of years of natural selection, and humans live for absorbing heat to accelerate molecular movements in physics, to decompose and synthesize organic molecules in chemistry, to reproduce ourselves and/or keep healthy in biology, and to obtain social benefits and take social responsibilities in social sciences; the former "aim" is the basis of the latter "aim".

For physics, the CBET reveals for the first time the primary driving force and mechanisms of evolution through integration with multiple disciplines including thermodynamics, in a comprehensive and comprehensible way. Although some views or theories in thermodynamics, such as negative entropy (negentropy) and the dissipative structure theory, have been employed to explain evolution [43-49], these views or theories are abstract, elusive, and controversial. We believe some of them are incorrect, mainly because their fundamental view that biological order is equal to thermodynamic order is incorrect [42-48], as detailed in **Supplementary File**. Biological order is accumulated slowly through long-term natural selection and requires relatively rapid movements of molecules, while thermodynamic order can increase rapidly by releasing heat to the surroundings and requires molecules to be relatively static (e.g. cold perfect crystals have low entropy and high thermodynamic order). When a seal is dying in ice and becoming cold, its entropy is declining, with increase in its thermodynamic order and decrease in its biological order. Biological order supports high entropy of an organism because it supports relatively rapid movements of molecules in the organism, like the fact that traffic order supports relatively rapid running of

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cars in a metropolis. Therefore, the view that biological order is equal to thermodynamic order is incorrect. The concept of negentropy is also incorrect because it was built on the incorrect view that biological order is equal to thermodynamic order [44]. Contrary to negentropy, the food we eat generate little information guiding the orderly movements of molecules and cells in our bodies, which are predominantly guided by the vast information encoded in our genomes which is accumulated through long-term natural selection.

The physicist James Clerk Maxwell created a demon to change the decaying tendency of the second law of thermodynamics. Maxwell's demon facilitates those molecules moving rapidly to enter a compartment, and inhibits those molecules moving slowly to enter this compartment [50]. It has not proved that this demon could exist in physics. In chemistry, natural selection can constitute “Maxwell's demon”, namely that some LHCBEs chemically change to HHCBEs after absorbing heat as per thermodynamics, and some formed HHCBEs can survive for some time, and they can be accumulated and separate themselves naturally from LHCBEs. The increase in the amount and diversity of HHCBEs under natural selection can lead to increase in the fitness of HHCBEs, and natural selection hence changes the second law of thermodynamics from a decaying force to a progressive force (**Figure 4**).

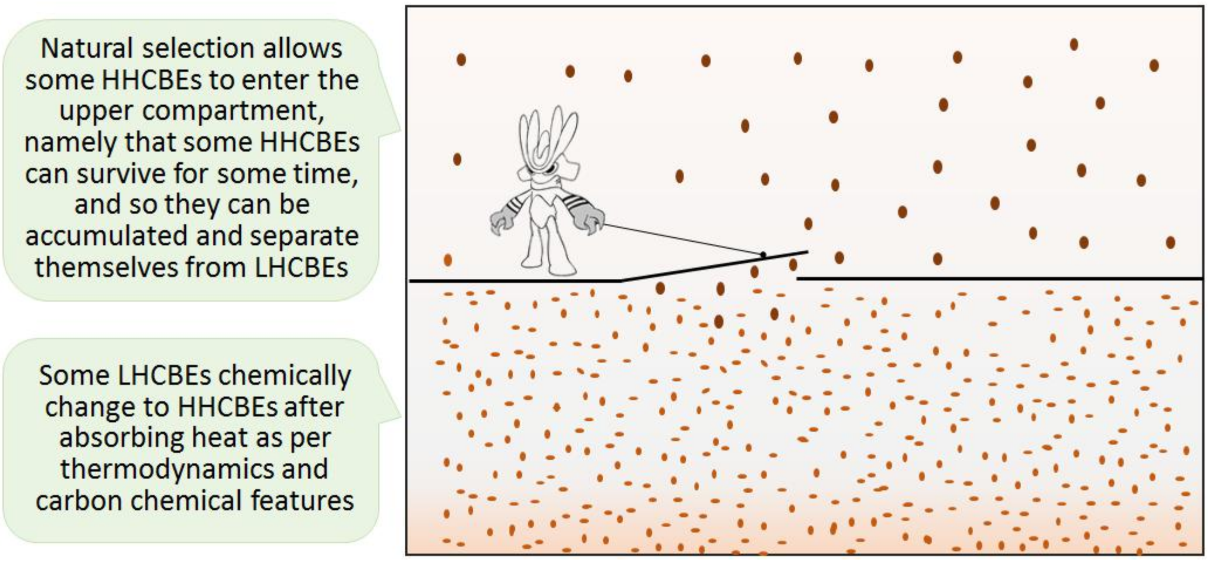

Figure 4. The reasons that natural selection can be “Maxwell's demon”. HHCBEs: higher-hierarchy carbon-based entities (CBEs), e.g. proteins compared with amino acids; LHCBEs: lower-hierarchy CBEs, e.g. amino acids compared with proteins

 doi:10.20944/preprints202010.0004.v10

9. Conclusions

This article deduces a novel evolutionary theory termed the CBET, which is quite different from previous mainstream evolutionary theories (**Figure 1** and **Table 1**), through integration of geology, physics, chemistry, and biology using logics for complex issues**.** The CBET suggests that evolution is the increase in the amount, diversity, and fitness of HHCBEs under natural selection and driven by the organic synthesis tendency on the Earth which stems from the thermodynamic features of the Earth. The CBET reveals the driving forces and mechanisms of life origin and life evolution from a panorama view.

The CBET reinterprets natural selection, provides better explanations for multiple evolutionary issues, and integrates with multiple advances which challenge previous evolutionary theories. It reveals the evolutionary basis of some important social notions. It refutes some incorrect thermodynamic notions regarding evolution and suggests that natural selection is "Maxwell's demon" in thermodynamics. The CBET is reliable as per its deduction and applications. Therefore, the CBET is more scientific and comprehensive than previous evolutionary theories, and could be the first bridge linking physics, biology, and social sciences through evolution. It could hence have great significance in natural sciences and social sciences, and it could spark various studies in multiple disciplines. Meanwhile, some details of the CBET should be optimized and extended in the future.

Supplementary File: A PPT file aiding readers to understand the CBET.

Acknowledgements: This study has not been supported by any funds. The author thank Meng Yang, Yi-Qing Chen, Ji-Wang Chen, Xu Zhang, and many other people for providing precious comments on this study.

Competing interests: The author declares no conflict of interest.

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