The Carbon-Based Evolutionary Theory (CBET)

Ji-Ming Chen

School of Life Sciences and Engineering, Foshan University, Guangdong, 528225, China

*Correspondence to: jmchen678@qq.com

Abstract

Evolution is fundamental to natural sciences and social sciences. Existing evolutionary theories are incomplete and unable to explain multiple evolutionary issues. To establish a comprehensive and comprehensible evolutionary theory, 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 (particularly the second law of thermodynamics), chemistry (particularly chemical reactions of CBEs), and biology (particularly the essence of reproduction, genomes, and natural selection). 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 (e.g. life origin, neutral mutation, speciation, and evolutionary tempos) than existing evolutionary theories. It reveals the physiochemical roots of biological evolution and the evolutionary roots of multiple social notions important to harmonious development of human society. It refutes from a novel respect some incorrect thermodynamic notions regarding evolution (e.g. negative entropy). It hence removes contradictions between physiochemistry, biology, and social sciences, and bridges them through evolution. The CBET is reliable as per its deduction and applications. Therefore, the CBET is more scientific and comprehensive than existing evolutionary theories, and could have great significance in natural sciences and social sciences. Meanwhile, the CBET is open to optimization and extension.

Keywords

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

1. Introduction

Evolution is fundamental to 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, physics the driving force, chemistry the molecular mechanisms, and biology the structures and genetic basis.[2] Therefore, a comprehensive evolutionary theory should be based on integration of these four disciplines, but existing evolutionary theories are largely based on one or two of these disciplines.[1-21] Therefore, they are all incomplete and hence difficult to explain multiple evolutionary issues, including life origin, macroevolution events (e.g. unicellular organisms evolved to multicellular organisms and ectotherm animals evolved to warm-blooded animals), the punctuated equilibrium tempo of evolution of many species with little change in long geological periods and significant changes in short geological periods, many genetic mutations neutral or even harmful in natural selection, some mutations occurring not randomly; some acquired epigenetic changes heritable and important for adaption of organisms.[1-21] They are also somehow contradictory to physics and social sciences (**Section 6).**

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, chemistry, 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, in exploring evolutionary issues.[23-28]

 doi:10.20944/preprints202010.0004.v11

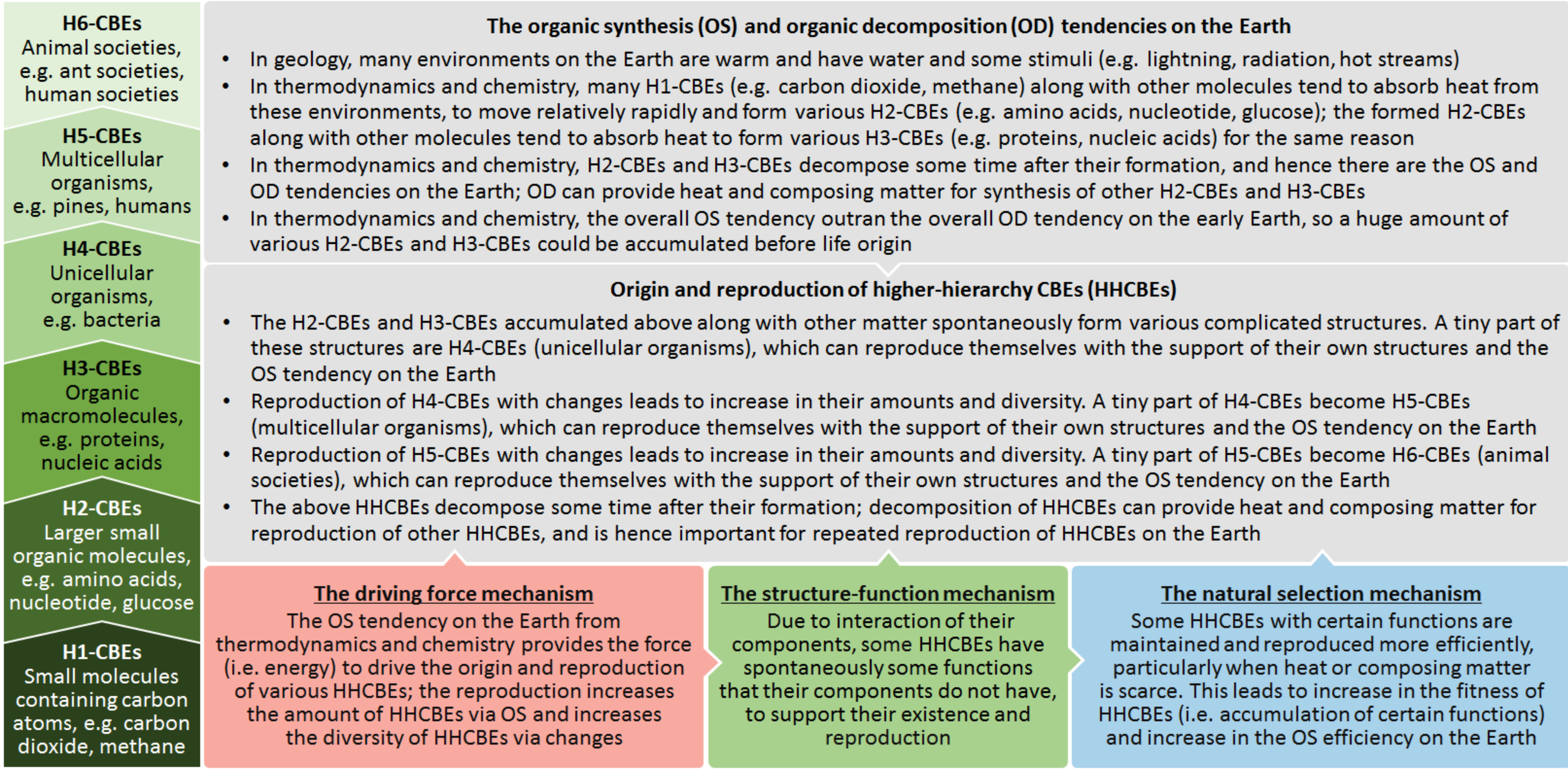

Figure 1. Major views of the Carbon-Based Evolutionary Theory (CBET). CBE: carbon-based entities. The existing mainstream evolutionary theories (i.e. Darwin's theory and the Modern Synthesis) largely correspond to only the blue part of this figure.

2. Hierarchies and functions of CBEs

We classify CBEs into six hierarchies (**Figure 1**). H1-CBEs are some small molecules containing carbon atoms (e.g. carbon dioxide, methane, and ethanol). H2-CBEs are larger small 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, and protozoa). H5-CBEs are multicellular organisms (e.g. grasses, trees, fishes, and humans). 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.

Notably, 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.

Some HHCBEs spontaneously have novel functions, which their components do not have, due to interaction of their components, namely 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 their amino acids residues. 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, and 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 (i.e. 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 and move relatively rapidly.

 doi:10.20944/preprints202010.0004.v11

In chemistry, many H1-CBEs (e.g. CO_2 and CH_4) along with some other small molecules (e.g. H_2S, H_2O, and NH_3) on the Earth have the tendency, after absorbing heat from vast warm environments on the Earth and hence moving more rapidly, to form H2-CBEs (e.g. amino acids, nucleotides, and glucose), particularly with a stimulus (e.g. lightning, radiation, or a hot stream). Likewise, 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 hence moving more rapidly, to form H3-CBEs (e.g. proteins, nucleic acids, lipids, and polysaccharides), particularly with a stimulus.[22] Altogether, there is the organic synthesis (OS) tendency on the Earth due to the thermodynamic features of the Earth.

In chemistry, H2-CBEs and H3-CBEs decompose some time after their formation, because they are formed with relatively fragile bonds.[2] This leads to the organic decomposition (OD) tendency on the Earth. OD can provide heat and composing matter for OS, and the OS and OD tendencies lead to repeated reproduction of H2-CBEs and H3-CBEs on the Earth **(Figure 2)**.

In chemistry, the overall OS tendency could outrun the overall OD tendency on the early Earth, because the then Earth had too many H1-CBEs, too few H2-CBEs and 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**).

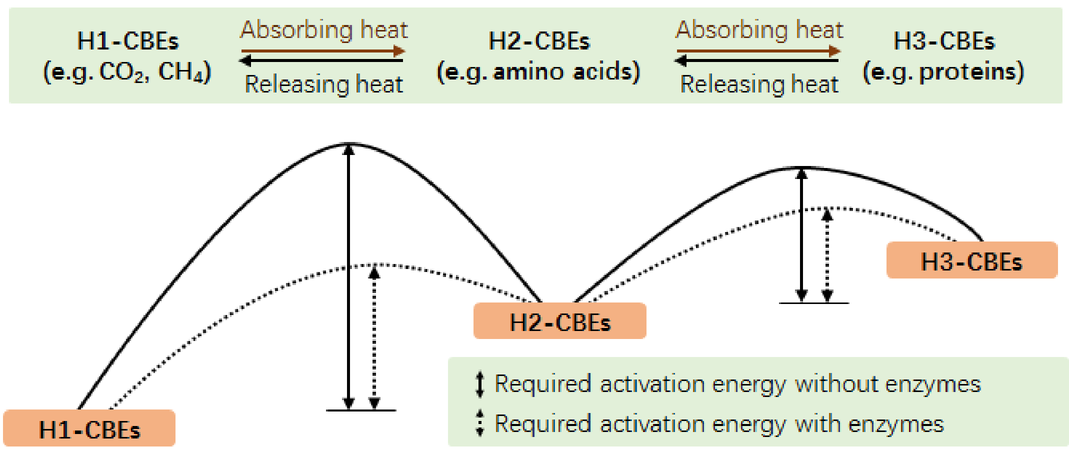

Figure 2. The tendencies of organic synthesis and decomposition on the Earth. These organic reactions require activation energy which can be provided by some stimuli and reduced by some enzymes.

3.2 Accumulation of enzymes due to the OS tendency

In chemistry, the above natural OS or OD reactions are very slow if they are not aided by enzymes, because they require relatively high activation energy (**Figure 2**).[2] Sometimes

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 18 August 2021 doi:10.20944/preprints202010.0004.v11

lightning, radiation, and other stimuli can provide activation energy for these reactions. Some H3-CBEs synthesized through the above natural OS are enzymes of some OS or OD reactions, and these enzymes can reduce significantly the required activation energy of these OS or OD reactions (**Figure 2**). These H3-CBEs can accelerate the above natural OS or OD reactions. Notably, each enzyme usually can catalyze only certain reactions, and enzymes can not determine the general directions (e.g. 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 OS before life origin.[29,30] The then Earth could be fetid like the Murchison meteorite which fell 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 or chemical evolution.[2,3] 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 of various H2-CBEs and H3-CBEs and some other molecules. H4-CBEs could reproduce themselves with two supports. One is the collaborative interaction (i.e. collaboration) of their components (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 with heat and composing matter. The other is the OS tendency on the Earth, which provides H4-CBEs with heat and composing matter for their reproduction. H4-CBEs also meet the OS tendency relatively efficiently, because they conduct various organic syntheses relatively efficiently using many enzymes, and their reproduction employs more copies of many enzymes to conduct more organic syntheses.

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 18 August 2021 doi:10.20944/preprints202010.0004.v11

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 of 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, a tiny part of the 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 could take 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. Like H4-CBEs, reproduction of many H5-CBEs (e.g. trees and tigers) is supported thermodynamically by the OS tendency on the Earth and functionally by the collaboration inside their complicated structures, including the collaboration among their cells and the collaboration among molecules in the cells. 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 H2-CBEs to H5-CBEs accumulated through the above natural organic syntheses decompose some time after their formation, as per their chemical features (see **Section 3.1**). Their decomposition provides composing matter and heat for natural OS of other HHCBEs. This supports the emergence and reproduction 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 composing 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. These animal societies (e.g. ant societies) could maintain their existence via reproduction of some individuals in the societies, with the support from the OS tendency on the Earth 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 diversity of HHCBEs, including accumulation of organic molecules, life origin, organism reproduction, and increase in roles of ecosystems, rely on and involve various organic syntheses. The OS tendency from the thermodynamic features of the Earth provides heat or energy to drive these increases. Therefore, the OS tendency is the primary driving force of the increases in the amount and diversity of HHCBEs, namely evolution of CBEs.

During the early history of the Earth, the amount and 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 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 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, namely the driving force mechanism, the structure-function mechanism, and the natural selection mechanism (**Figure 1**). The driving force mechanism, as mentioned in **Section 3.6,** leads to increase in the hierarchy and structural complexity of CBEs, increase in the amount and diversity of HHCBEs, and increase in the role of ecosystems, as deduced above (**Figure 1**).

4.1 The structure-function mechanism

The structure-function mechanism means that some HHCBEs spontaneously have novel functions, such as self-reproduction, non-random mutation, and sexual reproduction, which their components do not have, due to interaction inside HHCBEs, as mentioned in **Section 2**. All these functions should be under natural selection. They are hence prone to be accumulated if they can help existence or reproduction of the relevant HHCBEs. For example, self-reproduction of organisms is directly useful for increase in the amount of the relevant organisms and maintain the advantages of HHCBEs for natural selection. Non-random mutations in many microbial genomes and mammalian immunoglobulin genes facilitate to generate advantageous mutations and avoid disadvantageous mutations.[9,15] 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 ascribes this function to collaboration of various molecules in primitive cells.

The structure-function mechanism enables evolution to change evolution. For example, some H2-CBEs evolved from H1-CBEs, such as adenosine triphosphate, can 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 and organic decomposition involved in later evolutionary steps. Animals can gather and digest organic matter to generate heat and composing matter for their reproduction based on organic synthesis. Plants can gather water and some composing matter for their reproduction based on organic synthesis. 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.

4.2 The natural selection mechanism

Natural selection is a tautology. Namely, fit HHCBEs survive, and those HHCBEs that have survived are fit HHCBEs; fitter HHCBEs have larger amounts, and those HHCBEs having larger amounts are fitter HHCBEs. Previously, natural selection was criticized due to its tautology.[32] We think this tautology cannot refute natural selection but suggests that natural selection is really “natural”, 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 usually different HHCBEs are formed and maintained naturally at different rates. Therefore, long-term repeated formation of HHCBEs and its primary driving force from thermodynamics are the prerequisites of natural selection.

Natural selection leads to changes in the amount of different HHCBEs over time. These changes are determined by different reproduction rates of HHCBEs, particularly when heat or composing matter becomes scarce, and different decomposition rates or longevity of HHCBEs. These two aspects are co-determined by various structure-related functions or traits of an HHCBE, and they co-determine the overall fitness of an HHCBE.

With the increase in the amount and diversity of organisms, 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 amounts. 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. For example, an organism of great fitness in forests can be unfit in deserts. Moreover, evolution itself 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]

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

The above three mechanisms are interactive (**Figure 1**). The OS tendency from thermodynamics leads to generation of various HHCBEs (the driving force mechanism); due to interaction of their components, some HHCBEs spontaneously obtain certain novel functions to support their existence and reproduction (the structure-function mechanism); some HHCBEs shall have large amounts due to their certain functions, leading to increase of fitness of HHCBEs, namely accumulation of certain functions of HHCBEs which are useful for the existence and reproduction of HHCBEs (natural selection).

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.

Previously, 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 taken as 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.

Evolution itself adds novel secondary driving forces to evolution. For example, animal selection of sexual partners (sexual selection which is a function) 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.

4.3 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 existing evolutionary 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 is largely neglected by existing evolutionary theories), and the tendency that fitter HHCBEs shall have relatively larger amounts, which increases the fitness of HHCBEs.

Third, natural selection in existing evolutionary 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 had more fitness than fish, but because amphibians and fish both had 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 leading to thalassemia and diabetes).[3-5,37] This suggests a novel mechanism of sympatric speciation: different mutants of a species carrying various combinations of traits can all reproduce themselves 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, so their overall fitness could be adequate, and they 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 existing evolutionary 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

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 18 August 2021 doi:10.20944/preprints202010.0004.v11

evolutionary tempo of punctuated equilibrium. Additionally, the tempo of genomic changes can also lead to punctuated equilibrium, namely that some genomic changes, which add much fitness to the relevant species, occur at very low rates. For example, the H7N9 avian influenza virus, which was low pathogenic in China for four years, became highly pathogenic in around two months, and then kept highly pathogenic for over four years till date, because a special mutant of the virus with insertion of a few amino acids in the viral hemagglutinin gene, which added fitness to the virus in a stable environment (i.e. poultry), became prevalent in the two months.[38]

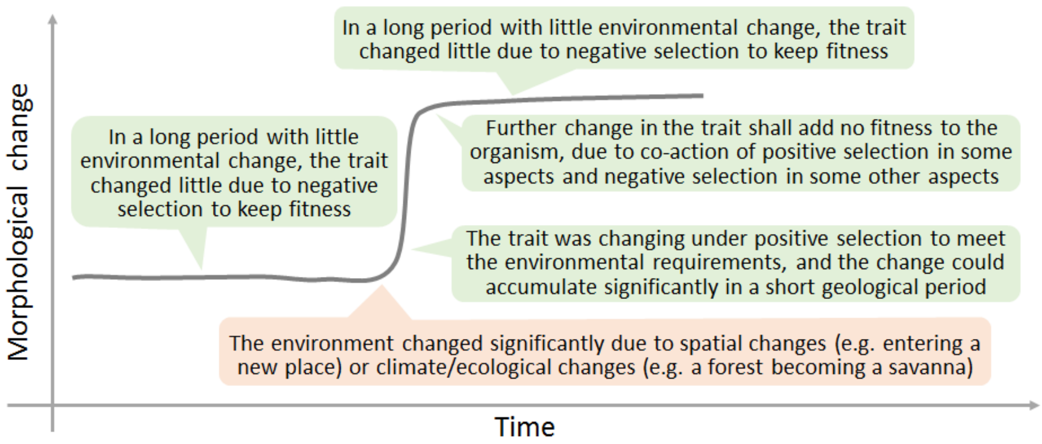

Figure 3. Co-action of positive selection and negative selection on the same trait leading to the punctuated equilibrium tempo.

Fifth, the targets of natural selection in existing evolutionary theories are individuals, populations, or genes,[34,39] while all genomic sites, all traits, and all hierarchies are 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.[39]

Sixth, natural selection in existing evolutionary theories targets 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.

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 18 August 2021 doi:10.20944/preprints202010.0004.v11

5. 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 second law of thermodynamics, 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 above five factors used in the integration are all important for a scientific, comprehensive, and comprehensible evolutionary theory, but almost all of them are neglected by existing evolutionary 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,[40-42] all require thermodynamic support and involve a process that molecules absorb heat to move relatively rapidly and synthesize organic molecules. The amount and 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, neutral or harmful mutations, sympatric speciation, punctuated equilibrium, effects of uninheritable traits on fitness, and altruism, than existing evolutionary theories (**Table 1**). These better explanations support the CBET.

Although we believe that the major views of the CBET shown in **Figure 1** are reliable, this theory is open to optimization and extension. 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

Issues	Existing explanations	Explanations of the CBET
The primary driving force of evolution	Natural selection, genetic drift, competition, or mutation (none of them directly involves energy)	The organic synthesis tendency on the Earth which stems from the thermodynamic features of Earth and the chemical features of carbon-based entities (CBEs)
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 CBEs; some higher-hierarchy CBEs (HHCBEs) obtain spontaneously novel functions due to interaction of their components; 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 amounts; 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, and both inheritable and uninheritable changes
Life origin	Mechanisms of life origin are explained with elusive concepts (e.g. negative entropy, dissipation systems, and self-organization)	The driving forces and mechanisms of life origin are explained with simple and concrete concepts (e.g. CBEs, organic synthesis, enzymes, and interaction of various molecules) via multidisciplinary integration;
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 roots 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, or due to the tempo of genomic changes
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 (e.g. altruism) may increase fitness in some aspects, but reduce fitness in some other aspects

6. 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. The CBET reveals the physiochemical roots of evolution, and so thoroughly transfers evolutionary theories from hypotheses to scientific theories. It provides better explanations for multiple evolutionary issues than existing evolutionary theories. Therefore, the CBET is more scientific and comprehensive than existing evolutionary theories.

For social sciences, the CBET reveals the evolutionary roots of various important notions for harmonious development of human society. Existing evolutionary theories highlight selfishness, competition, genetics, 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.[43] The CBET reveals the importance of fitness and diversity, selfishness and altruism, competition and collaboration, obeying rules and extending freedom, human welfare and environment protection, genetic advantages and uninheritable efforts, from the evolutionary perspective. These notions of the CBET are all important for harmonious development of human society. The CBET also suggests that humans live for absorbing heat to accelerate molecular movements in physics, to decompose and synthesize organic molecules in chemistry, to reproduce ourselves and keep healthy in biology, and to obtain social benefits and undertake social responsibilities in social sciences; the former “aims” are the basis of the latter “aims”.

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 and the dissipative structure theory, have been employed to explain the contradiction between evolution and the second law of thermodynamics,[44-50] these views or theories are abstract, elusive, and controversial, and largely neglect the long-term effect of natural selection. We believe some of them are incorrect, mainly because their fundamental view that biological order is equal to thermodynamic order in entropy is incorrect,[43-49] as detailed in **Supplementary File**. Biological order is primarily 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 releasing heat to the surroundings, 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 cars in a metropolis. Therefore, the view that biological order is equal to thermodynamic order in entropy is incorrect, and the concept of negative entropy based on this view is also incorrect.[45] Contrary to negative entropy, 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 and accumulated through long-term natural selection.

The physicist James Clerk Maxwell created a "demon" to change the second law of thermodynamics from a decaying force to a progressive force. Maxwell's demon allows rapidly-moving molecules to enter a compartment, and inhibits slowly-moving molecules to enter this compartment.[51] It has not proved that this demon could exist in physics. We think that, in chemistry, natural selection constitutes Maxwell's demon, as fit HHCBEs can survive for some time and differentiate themselves naturally from LHCBEs, and fitter HHCBEs shall have relatively larger amounts, which increases the fitness of HHCBEs and hence has the same effect of Maxwell's demon (**Figure 4**).

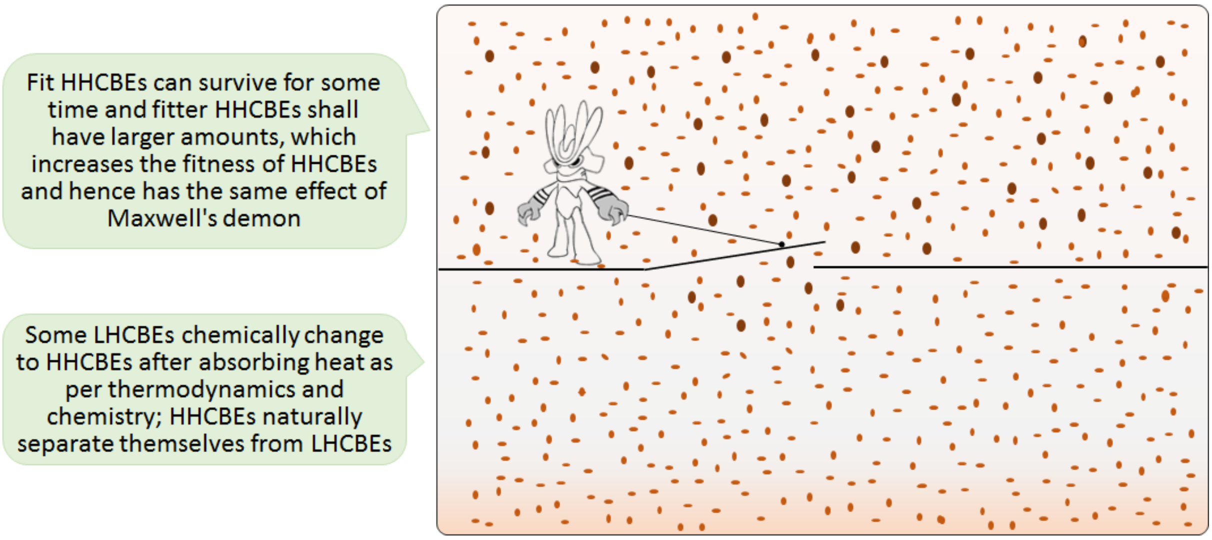

Figure 4. The reasons that natural selection can be "Maxwell's demon". HHCBEs: higher-hierarchy carbon-based entities (CBEs); LHCBEs: lower-hierarchy CBEs.

7. Conclusions

This article deduces a novel evolutionary theory termed the CBET, which is expanded significantly from the existing 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 OS tendency on the Earth, which stems from the thermodynamic features of the Earth. The CBET reveals the steps, driving forces, and mechanisms of life origin and life evolution from a panorama view.

The CBET reinterprets natural selection and provides better explanations for various evolutionary issues. It reveals the physiochemical roots of evolution and the evolutionary roots of various important social notions. It suggests that natural selection is "Maxwell's demon" in thermodynamics and refutes some incorrect thermodynamic notions regarding evolution from a novel respect, namely that biological order is different from thermodynamic order in entropy. The CBET hence removes the contradictions between physiochemistry, biology, and social sciences, and bridges them through evolution. It is reliable as per its deduction and applications. Therefore, the CBET is more scientific and comprehensive than existing evolutionary theories, and could have great significance in natural sciences and social sciences. Meanwhile, the CBET is open to optimization and extension.

Supplementary File: A PPT file aiding reviewers to better 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.

References

1. Chen, J.M. (2000). A new evolutionary theory deduced mathematically from entropy amplification. Chin Sci Bul. ***45,*** 91–96. https://doi.org/10.1007/BF02884912
2. Chen, J.M., Chen, J.W. (2000). Root of science—the driving force and mechanisms of the extensive evolution (Science Press).
3. Futuyma, D.J., Kirkpatrick. M. (2017). Evolution (Sinauer Press).
4. Huneman, P., Walsh, D.M. (2017). Challenging the Modern Synthesis: adaptation, development, and inheritance (Oxford University Press).
5. Preiner, M., Asche, S., Becker, S., et al. (2020). The future of origin of life research: bridging decades-old divisions. Life (Basel). ***10,*** 20. http://doi.org/10.3390/life10030020

6. Pagel, M. (2009). Natural selection 150 years on. Nature. ***457,*** 808–811. https://doi.org/10.1038/nature07889
7. d'Ischia, M., Manini, P., Moracci, M., et al. (2019). Astrochemistry and astrobiology: materials science in wonderland? Int J Mol Sci. ***20,*** 4079. http://doi.org/10.3390/ijms20174079
8. Orgel, L. (2006). In the beginning. Nature. ***439,*** 915–915. https://doi.org/10.1038/439915a
9. Fitzgerald, D.M., Rosenberg, S.M. (2019). What is mutation? A chapter in the series: How microbes "jeopardize" the modern synthesis. PLoS Genet. ***15,*** e1007995. https://doi.org/10.1371/journal.pgen.1007995
10. Koonin, E.V. (2009). Darwinian evolution in the light of genomics. Nucleic Acids Res. ***37,*** 1011–1034. http://doi.org/10.1093/nar/gkp089
11. Dickins, T.E., Rahman, Q. (2012). The extended evolutionary synthesis and the role of soft inheritance in evolution. Proc Biol Sci. ***279,*** 2913–2921. http://doi.org/10.1098/rspb.2012.0273
12. Casillas, S., Barbadilla, A. (2017). Molecular population genetics. Genetics. ***205,*** 1003–1035. https://doi.org/10.1534/genetics.116.196493
13. Walker, S.I. (2017). Origins of life: a problem for physics, a key issues review. Rep Prog Phys. ***80,*** 092601. https://doi.org/10.1088/1361-6633/aa7804
14. Seager, S. (2013). Exoplanet habitability. Science. ***340,*** 577–581. http://doi.org/10.1126/science.1232226
15. Olivieri, D.N., Mirete-Bachiller, S., Gambón-Deza, F. (2020). Insights into the evolution of IG genes in Amphibians and Reptiles. Dev Comp Immunol. ***114,*** 103868. https://doi.org/10.1016/j.dci.2020.103868
16. Dodd, M.S., Papineau, D., Grenne, T., et al. (2017). Evidence for early life in earth's oldest hydrothermal vent precipitates. Nature. ***543,*** 60–64. http://doi.org/10.1038/nature21377
17. Proskurowski, G., Lilley, M.D., Seewald, J.S., et al. (2008). Abiogenic hydrocarbon production at lost city hydrothermal field. Science. ***319,*** 604–607. http://doi.org/10.1126/science.1151194
18. Benton, M.J. (2009). The Red Queen and the Court Jester: species diversity and the role of biotic and abiotic factors through time. Science. ***323,*** 728–732. http://doi.org/10.1126/science.1157719
19. Lynch, M. (2007). The frailty of adaptive hypotheses for the origins of organismal complexity. Proc Natl Acad Sci U S A. ***104(Suppl 1),*** 8597–8604. http://doi.org/10.1073/pnas.0702207104
20. DeVoe, H. (2020). Thermodynamics and chemistry (2nd Ed). http://www2.chem.umd.edu/thermobook/v10-screen.pdf. Accessed on Sep. 20, 2020.

21. Borgnakke, C., Sonntag, R.E. (2013). Fundamentals of Thermodynamics (John Wiley & Sons).
22. Carbon. https://en.wikipedia.org/wiki/Carbon. Accessed on Sep. 20, 2020.
23. Rohde, R.A., Muller, R.A. Cycles in fossil diversity. Nature. 2005;***434,*** 208–210. http://doi.org/10.1038/nature03339
24. Percival, L.M.E., Ruhl, M., Hesselbo, S.P., et al. (2017). Mercury evidence for pulsed volcanism during the end-Triassic mass extinction. Proc Natl Acad Sci U S A. ***114,*** 7929–7934. http://doi.org/10.1073/pnas.1705378114
25. Fields, B.D., Melott, A.L., Ellis, J., et al. (2020). Supernova triggers for end-Devonian extinctions. Proc Natl Acad Sci U S A. ***117,*** 21008–21010. http://doi.org/10.1073/pnas.2013774117
26. Bader, J., Jungclaus, J., Krivova, N., et al. (2020). Global temperature modes shed light on the Holocene temperature conundrum. Nat Commun. ***11,*** 4726. https://doi.org/10.1038/s41467-020-18478-6
27. Nowak, M., Tarnita, C., Wilson, E. (2010). The evolution of eusociality. Nature. ***466,*** 1057–1062. https://doi.org/10.1038/nature09205
28. Styrsky, J.D., Eubanks, M.D. (2007). Ecological consequences of interactions between ants and honeydew-producing insects. Proc Biol Sci. ***274,*** 151–164. http://doi.org/10.1098/rspb.2006.3701
29. Spitzer, J., Pielak, G.J., Poolman, B. (2015). Emergence of life: Physical chemistry changes the paradigm. Biol Direct. ***10,*** 33. https://doi.org/10.1186/s13062-015-0060-y
30. Follmann, H., Brownson, C. (2009). Darwin's warm little pond revisited: From molecules to the origin of life. Naturwissenschaften. ***96,*** 1265–1292. http://doi.org/10.1007/s00114-009-0602-1
31. Robertson, M.P., Joyce, G.F. (2012). The origins of the RNA world. Cold Spring Harb Perspect Biol. ***4(5),*** a003608. http://doi.org/10.1101/cshperspect.a003608
32. Hunt, T. (2014). Reconsidering the logical structure of the theory of natural selection. Commun Integr Biol. ***7,*** e972848. https://doi.org/10.4161/19420889.2014.972848
33. McGee, M.D., Borstein, S.R., Meier, J.I., et al. (2020). The ecological and genomic basis of explosive adaptive radiation. Nature. ***586,*** 75-79. https://doi.org/10.1038/s41586-020-2652-7
34. Nei, M. (2013). Mutation-driven evolution. Oxford, UK: Oxford University Press, 2013.
35. Martin, W.F., Sousa, F.L., Lane, N. (2014). Energy at life's origin. Science. ***344,*** 1092–1093. https://doi.org/10.1126/science.1251653
36. Sousa, F.L., Thiergart, T., Landan, G., et al. (2013).Early bioenergetic evolution. Philos Trans R Soc Lond B Biol Sci. ***368,*** 20130088. http://doi.org/10.1098/rstb.2013.0088
37. Yizhak, K., Aguet, F., Kim, J., et al. (2019). RNA sequence analysis reveals macroscopic somatic clonal expansion across normal tissues. Science. ***364,*** eaaw0726.

38. Chen, J., Sun, Y. (2011). Variation in the analysis of positively selected sites using nonsynonymous/synonymous rate ratios: An example using influenza virus. PLoS One. ***6,*** e19996. http://doi.org/10.1371/journal.pone.0019996
39. Liu, S., Zhuang, Q., Wang, S., et al. (2020). Control of avian influenza in China: Strategies and lessons. Transbound. Emerg. Dis. ***67***, 1463–1471. https://doi.org/10.1111/tbed.13515
40. Hutchison, C.A. 3rd, Chuang, R.Y., Noskov, V.N., et al. (2016). Design and synthesis of a minimal bacterial genome. Science. ***351,*** aad6253. https://doi.org/10.1126/science.aad6253
41. Service, R.F. (2016). Synthetic biology. Synthetic microbe has fewest genes, but many mysteries. Science. ***351,*** 1380–1381. https://doi.org/10.1126/science.351.6280.1380
42. Stobart, C.C., Moore, M.L.(2014). RNA virus reverse genetics and vaccine design. Viruses. ***6,*** 2531–2550. https://doi.org/10.3390/v6072531
43. Rudman, L.A., Saud, L.H. (2020). Justifying social inequalities: The role of social Darwinism. Pers Soc Psychol B. ***46***, 1139–1155. https://doi.org/10.1177/0146167219896924
44. Boltzmann, L. (1974). The second law of thermodynamics. In Theoretical physics and philosophical problems, B.F. McGuinness ed. (Springer), pp. 13–32.
45. Schrödinger, E. (1944). What is life—the physical aspect of the living cell (Cambridge University Press).
46. Wilson, J.A. (1968). Entropy, not negentropy. Nature, ***219,*** 535–536. https://doi.org/10.1038/219535a0
47. Kleidon, A. Life, hierarchy, and the thermodynamic machinery of planet Earth. Phys Life Rev. ***7,*** 424–460. https://doi.org/10.1016/j.plrev.2010.10.002
48. Ramstead, M.J.D., Badcock, P.B., Friston, K.J. (2018). Answering Schrödinger's question: A free-energy formulation. Phys Life Rev. ***24,*** 1–16. https://doi.org/10.1016/j.plrev.2017.09.001
49. Jennings, R.C., Belgio, E., Zucchelli, G. (2018). Photosystem I, when excited in the chlorophyll Qy absorption band, feeds on negative entropy. Biophys Chem. ***233,*** 36–46. https://doi.org/10.1016/j.bpc.2017.12.002
50. Bejan, A. (2017). Evolution in thermodynamics. Appl Phys Rev. ***4,*** 011305. https://doi.org/10.1063/1.4978611.
51. Linke, H., Parrondo, J.M.R. (2021). Tuning up Maxwell's demon. Proc Natl Acad Sci U S A. ***118,*** e2108218118. https://doi.org/10.1073/pnas.2108218118.