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On the Adaptability Range, Self-Selection, and Economic Nature of Biological Evolution

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ABSTRACT

This article employs a combined approach of biology and economics to reveal that biological evolution has an economic nature, evolving towards improved energy efficiency. The orthodox Darwinian theory of evolution describes evolution as the random variation of organisms and their survival through natural selection. In fact, the natural environment itself is a constantly changing context, and the strategy to adapt to this change is to enhance behavioral capabilities, thereby expanding the range and dimensions of behavior. Therefore, the improvement of behavioral capabilities is an important aspect of evolution. The enhancement of behavioral capabilities expands the range of adaptation to the natural environment and increases the space for behavioral choices. Within this space of behavioral choices, some options are more effective and superior to others; thus, the ability to select is necessary to make the improved behavioral capabilities more beneficial to the organism itself. The birth and development of the brain serve the purpose of selection. By using the brain to make selections, at least the "better" behavior will be chosen between two alternatives. Once the better behavior yields better results, and the organism can associate these results with the corresponding behavior, it will persist in this behavior. The persistent repetition of a behavior over generations will form a habit. Habits passed down through generations constitute a new environment, causing the organism's genes to activate or deactivate certain functions, ultimately leading to genetic changes that are beneficial to that habit. Since the brain's selection represents the organism's self-selection, it differs from random variation; it is also a rational selection, choosing behaviors that either obtain more energy or reduce energy consumption. Thus, this evolution possesses an economic nature.

1. THE ECONOMIC NATURE OF BIOLOGICAL EVOLUTION

The mainstream Darwinian Theory of evolution posits that biological evolution primarily relies on the variation and natural selection of organisms. Variation is random and lacks a fixed direction, and the natural environment is also constantly changing. A particular variation may happen to adapt to the altered natural environment and thus survive. Therefore, evolution is often perceived as lacking direction. However, this does not seem to be the case. In the vast majority of instances, a certain variation cannot be easily judged as good or bad, as it all depends on its adaptation to the environment. However, the most common or successful variations among the various possibilities are often the more economical variations, which may be reflected in lower costs or enhanced capabilities. This type of variation is typically superior to others in adapting to all environmental changes. The changes in the natural environment are diverse, but for living beings, there are essentially only two types: harsher or more abundant conditions. When the environment becomes harsher, variations with higher energy efficiency are more likely to survive; when the environment becomes more abundant, those variations thrive better and reproduce more offspring.

The establishment of evolutionary theory itself was inspired by economists. It is said that when Darwin was 29 years old, he accidentally read the economist Malthus' "An Essay on the Principle of Population," in which a particular sentence struck him: "We may feel assured that the increase of population will be checked by something." [1] In ***The Origin of Species***, he states, "Hence, as more individuals are produced than can possibly survive, there must in every case be a struggle for existence, either one individual with another of the same species, or with the individuals of distinct species, or with the physical conditions of life. It is the doctrine of Malthus applied with manifold force to the whole animal and vegetable kingdoms." [2] The reason for the "struggle for existence" is that survival resources are scarce for living beings. "Scarcity" implies that supply is less than demand, which is the foundation upon which economics is built. It is precisely because resources are scarce that people must adopt more economical methods—a main thread throughout millions of years of human history. Placing this premise in the biological world, the struggle for existence indicates that living beings need to survive more economically.

Speaking in more abstract terms, economics refers to the conservation of energy. It means either achieving a certain activity or function with less energy or achieving more activities or functions with the same amount of energy. Among various activities or functions, the acquisition of energy is the most important aspect. Professor Nick Lane, a biologist, primarily uses energy analysis to examine the evolution of life in his book, ***The Vital Question***. He created the concept of "average energy per gene" and uses ATP as the unit to represent energy. He states, "For a cell to grow, manufacture more organic molecules, double, and ultimately self-replicate, it must necessarily consume more energy and more carbon atoms." "The earliest cells may have had to produce 40 tons of waste to synthesize 1 gram of cell material" [3]. Using the economic definition, **life is a system in which the continuous acquisition of energy exceeds its consumption.** Borrowing from economics, we can also define "**survival**" as a state where **energy supply exceeds energy consumption at any given moment**, where "energy supply" refers to the total energy acquired at that time plus the organism's energy reserves. **The "fittest" are the organisms that can survive. "Survival of the fittest" means that among all competing organisms, those with the highest energy efficiency will ultimately survive**.

The so-called "energy efficiency" can be divided into absolute energy efficiency and relative energy efficiency. The "average energy per gene" proposed by Professor Nick Lane, mentioned earlier, is a measure of **absolute energy efficiency**. However, this does not explain the issue of "survival of the fittest". Although the absolute energy efficiency of eukaryotes is much higher than that of bacteria, a large number of bacteria still survive. **Relative energy efficiency** refers to the state where energy supply exceeds energy consumption, which can be expressed as a relative number—*i.e.*, taking the energy supply as 1 and using the difference between energy supply and energy consumption as a percentage of the energy supply. The higher this percentage (less than 1), the more adapted the organism is, and the greater its chances of survival and reproduction. In other words, no matter how low the absolute energy efficiency of a species is, **as long as its relative energy efficiency is greater than zero, it can survive**. Conversely, although a species may have very high absolute energy efficiency, if its energy consumption is also very high, its relative energy efficiency may not be high, putting it at risk of extinction. **We can define the death of an individual or the extinction of a species using the criterion of relative energy efficiency being less than zero**. Changes in the natural environment will ultimately be reflected in the energy efficiency of living beings themselves. For example, a decrease in temperature can reduce energy acquisition while increasing energy consumption due to the need to keep warm, which may result in a relative energy efficiency that is lower than zero. Therefore, **we can directly use changes in energy efficiency to describe alterations in the natural environment**.

There are many types of biological evolution, but from an economic perspective, there are roughly two categories. One is what Darwin referred to as "variety," which encompasses all kinds of random variations within the same species and is economically neutral. From the standpoint of relative energy efficiency, these varieties compete for the same resources. In a specific environment, the relative energy efficiency of one variety may be higher than that of others, making it the most suitable. The other type is "upgrading," which is economic in nature, meaning the absolute energy efficiency of the mutated species is significantly higher than that of other species, sometimes even an order of magnitude greater. This type of variation has a directional quality. We can use relative energy efficiency to measure competition among varieties within a species and absolute energy efficiency to measure upgrading among different species. However, when Darwin discussed the struggle for existence, he focused more on competition among varieties of the same species. Darwin seldom discussed upgraded variation and did not explain how fish evolved into amphibians in ***The Origin of Species***. Nevertheless, he pointed out in ***The Descent of Man*** that humans must have evolved from lower animals. The theories of biological evolution that emerged after him lead us to believe that organisms on Earth have evolved from simple to complex forms, from single-celled organisms to humans.

We can use the economic method to distinguish between these two types of variation. Suppose a car manufacturer excels at producing vehicles adapted to low temperatures; its energy efficiency is higher than that of other variants. This higher efficiency may arise purely by chance due to the utility increase or energy savings relative to other car types resulting from adaptation to cold climates, while the latter suffer reduced energy efficiency due to a lack of such adaptation. Similar situations occur with variations within a species. As Darwin observed, "if several varieties of wheat be sown together, and the mixed seed be resown, some of the varieties which best suit the soil or climate, or are naturally the most fertile, will beat the others and thus yield more seed, and will consequently in a few years quite supplant the other varieties" [2]. Explained through economic logic, when the relative energy efficiency of a variety is higher than that of its competitors, it can rely on a greater energy surplus to reproduce more offspring, while the other varieties can only produce fewer offspring. After a few generations, the most optimal variety will completely replace the others. This situation is similar to product competition in the market. When the production efficiency of a product exceeds that of similar products, the manufacturer can achieve greater profits; it can either lower prices or expand production, ultimately squeezing out the products of other competitors.

The utility change brought about by upgraded variation can be described by absolute energy efficiency, represented by MU, where M is a number much greater than 1. According to the discussion in the text, this number is at least several times greater or even exceeds 1000. When a product in the market appears that exceeds the utility of the original product by 10 times, it can absolutely surpass the original product. In the biological world, this is referred to as upgraded variation. For example, a large biological molecule may randomly drift and incidentally absorb the energy it encounters, but there can be inconsistencies in the energy supply. An important variation is the formation of the cell membrane. "It can maintain a stable metabolic environment within the cell and also regulate and select the substances entering and leaving the cell" [4]. The cell membrane serves as the outer shell of the organism. Its function is to retain temporarily unused energy, preventing other macromolecules from taking it away. Additionally, this cell membrane can selectively "consume" energy-rich substances from the environment, expel waste from within, and block intruders from the outside. The cell membrane resembles a human house, which represents the initial property right.

The second upgraded variation in the history of life is the emergence of eukaryotes. According to Professor Nick Lane's calculations, the average energy per gene in bacteria is only 1/5000 of that in eukaryotes. This is why bacteria cannot grow as large as eukaryotes. Although ATP synthesis increased 625-fold, energy expenditure increased 15,000-fold, resulting in the average energy per gene copy actually decreasing to 1/25 of the original [5]. The average energy per gene in eukaryotes is 5000 times that of bacteria, suggesting that their energy acquisition efficiency is at least 5000 times higher. The transition from bacteria to eukaryotes is extremely rare and incidental, according to Professor Nick Lane, occurring only once in billions of years on Earth. This transition happened when some bacteria accidentally entered an archaeal cell and became endosymbionts. During this process, the bacteria evolved into linear organelles whose function is to produce energy. "Only when the cell is equipped with mitochondria can it possibly upgrade to a large and active phagocytic cell" [5]. This has formed a complementary relationship between the host and the endosymbiont. Once the bacteria had a host for protection, the genes responsible for producing the cell wall became redundant, allowing them to discard these genes. As a result, the endosymbionts could replicate faster, gaining an advantage over other bacteria and eventually replacing them.

In fact, there are more genes that can be discarded than those that remain. Professor Nick Lane stated that 99% of genes have been discarded in the mitochondria of all animals. Discarding genes also reduces energy consumption, and "the function of mitochondria is precisely to produce ATP" (*i.e.*, energy). "In the vast majority of genes discarded by mitochondria, some… continue their previous work," which means saving energy for energy production without reducing overall output. Other genes that discard their original functions become "genetic raw materials for eukaryotic evolution, some of which give rise to entire gene families, where each gene in the family can specialize and perform specialized tasks" [3]. This means that the structure of host endosymbionts enables eukaryotes to acquire more specialized functions, benefiting both parties. Biologists have proposed that "there is a metabolic 'mutualism' relationship between hosts and endosymbionts, which means that they exchange the substrates needed for growth, not just energy," Professor Nick Lane concluded. "The more endosymbionts in the host, the more they can acquire. The faster the growth of the substrate, the better the living conditions for endosymbionts" [3].

After the emergence of eukaryotes, the evolution of organisms has progressed along the path of energy conservation. There are two important mechanisms: one is economies of scale; the other is division of labor and specialization. Professor Zhang Tinghua pointed out that the formation of the cell membrane allows more genes to co-polymerize within the cell. From an economic perspective, agglomeration creates economies of scale, meaning that as quantity increases, unit costs decrease, which directly leads to energy savings. According to Professor Zhang Tinghua, "the specialized division of labor in genes leads to the clustering of many genes together" [4], and the clustering of genes in cells further promotes specialized division of labor. This aligns well with economic logic. Smith's theorem states that "division of labor is limited by the scope of the market." In other words, an increase in market size promotes division of labor. For example, if the demand in a village is insufficient for a shoemaker to specialize in shoe repair, this specialization becomes feasible when expanding to the level of a township. This principle appears to apply at the subcellular level as well. As Professor Zhang Tinghua noted, in the aggregation of nucleic acids and proteins in cells, "nucleic acids (genes) are responsible for the inheritance of cooperative traits, while proteins are responsible for the daily affairs (survival) of cooperative organisms," resulting in "the first specialized division of labor and cooperation in the history of life evolution" [4].

In the later stages of biological evolution, the main approaches have included aggregation, economies of scale, division of labor, and specialization, which have led to the formation of species with higher energy efficiency. For example, the transition from single-celled organisms to multicellular organisms. Multicellular organisms not only save unit energy but also establish division of labor and specialization among their components. Gradually, living organisms develop various specialized organs responsible for functions such as digestion, the nervous system, movement, respiration, circulation, excretion, reproduction, and endocrine regulation. These organs are then integrated into the main body systems. From a species perspective, this represents a progression "from simple to complex, from lower to higher, from aquatic to terrestrial" [4]. The evolutionary sequence spans from single-celled organisms to multicellular organisms, from thallophytic plants to vascular plants, from coelenterates to flatworms, from lower invertebrates to arthropods, from fish to amphibians, from invertebrates to vertebrates, to mammals, and finally to primates, culminating in humans. If measured by the "average energy per gene" proposed by Professor Nick Lane, these upgraded variations would represent significant leaps in energy efficiency.

Since biological evolution has an economic nature, we can use "relative energy efficiency" and "absolute energy efficiency" to describe or define some basic concepts in biology.

Variation is the change in an organism that leads to new relative energy efficiency or absolute energy efficiency. **Random Variation** refers to the fact that variation does not necessarily improve energy efficiency, and its outcomes are uncertain.

Adaptation occurs when the relative energy efficiency of an organism is greater than zero in a specific natural environment. **Adapting** involves a process of change that adjusts a state of relative energy efficiency from below zero to a positive state, whether through genetic, behavioral, or environmental modifications.

Changes in Natural Environment can affect living organisms, leading to alterations in their relative energy efficiency. **Mass Extinction** is caused by changes in the natural environment that result in the relative energy efficiency of the entire population falling below zero.

Natural Selection refers to the survival of the most efficient variant of the same species in a specific natural environment, while other variants are eliminated due to their relative energy efficiency being either below zero or lower than that of the highest variant.

2. ANOTHER DIMENSION OF BIOLOGICAL EVOLUTION - ADAPTABILITY RANGE

The natural environment is constantly changing, and different regions on Earth have distinct natural environments. Biological species generally adapt to these varying environments through variant evolution. As Darwin cited the example of Darwin's finches on the Galápagos Islands, the beak sizes of the subspecies of finches on different islands formed a series [6]. This is clearly the result of the adaptation of these various bird varieties to their respective environments. The term "adaptation" refers to the body structure and behavior of the birds being suited to their specific natural environments. Therefore, variant evolution is a strategy of adaptation. However, this strategy appears to be quite costly. The emergence of adaptive varieties is accidental, and the adaptation process is characterized by the extinction of non-adaptive varieties and the survival of adaptive ones. This process requires a long time to complete. Once adapted to a specific natural environment, these species cannot migrate to other areas with different conditions. If the natural environment changes, their already adapted body structures may become maladaptive again, leading to extinction once more. The main problems with this adaptive strategy are its low success rate, irreversibility, lack of flexibility, and inability to be reconstructed.

Faced with the diversity and changes in the natural environment, one can consider a method of adaptive change. This involves adjusting biological states or behaviors in response to different environments or environmental changes. Such responses can manifest in two dimensions. One is the state dimension; another is the behavior dimension. Regarding the state dimension, biologists have found that the pearl nautilus and the white nautilus exhibit significant differences in appearance, yet they are genetically the same species. They believe this may be due to the fact that these organisms encountered different environments during their early life, such as varying temperatures, food sources, or predators, leading them to adopt different coping strategies, which makes them appear to be two distinct species [7]. Another finding is that "the previously accepted two species of giant North American mammoths (Columbian mammoth and woolly mammoth) are genetically the same, but their phenotypes are determined by the environment" [7]. To explain the phenomenon of unchanged genes alongside behavioral and morphological changes, biologists have developed the concept of epigenetics. This theory posits that DNA can be attached by small molecules that can turn certain functions in genes on or off. This allows for changes in the behavior or state of organisms without altering their genetic code.

However, limitations of the state change include rigidity, difficulty in reversal, and lack of plasticity. A more flexible strategy for adapting to the environment is to develop behavioral abilities. It is important to distinguish between behavior, action, and movement. Movement refers to the change of an object following physical laws, such as the rotation of planets around the sun. Action is a movement characterized by direction and speed selection, such as the swimming of fish. In contrast, behavior encompasses complex and detailed actions, including tool-making, artistic performances, or religious rituals. Behavior (including action) provides biological subjects with a broader behavioral repertoire, allowing for adaptation to a wider range of natural environmental changes. Consequently, **one direction for the evolutionary advancement**

of life is to enhance behavioral abilities to expand adaptability. The advantage of behavioral change over the state change strategy lies in its flexibility and reversibility; it can be altered instantly and adjusted at any time. This adaptability allows organisms to respond to changes in the natural environment, ultimately reducing the costs associated with adapting to a constantly changing world.

It can be said that the evolution from plants to animals represents a profound upgrade. Plants cannot move, and their energy intake is solely passive; if they could move, they would be able to actively expand their energy acquisition range. Another advantage of mobility is the expansion of the Adaptability range, and its dimensions primarily include temperature, humidity, wind, food abundance, and predator strength. These factors can determine the survival or extinction of organisms. The wider the range of motion of organisms, the stronger their adaptability to the environment, and the greater their chances of survival. However, movement consumes energy. The key to this strategy is to improve absolute energy efficiency so that the energy gained from movement exceeds the energy expended. Additionally, relative energy efficiency must be adjusted through movement, meaning that energy acquisition should be increased while energy consumption is reduced, thereby preventing death due to relative energy efficiency dropping to zero or below. For example, migratory animals move to warmer locations in winter, reaching areas with more abundant resources while minimizing the energy spent on maintaining warmth; their relative energy efficiency is adjusted to be higher than zero by changing the environment. Therefore, movement is a form of adaptation; adaptation is the adjustment to change.

Assuming the range of environmental changes is ΔN and the Adaptability range adjusted by the organism's movement is ΔB: when ΔB is significantly smaller than ΔN, the organism may become extinct due to maladaptation to some changes in the natural environment. When ΔB is roughly equal to and overlaps with ΔN, the organism can basically survive. When ΔB is greater than ΔN and completely covers it with surplus, the organism is able to cope with the environment flexibly and is considered the fittest. Of course, in a deeper discussion, mobility capabilities are not only about geographical movement but also about functional changes, such as running speed. The predators of an organism are also part of its natural environment. When an organism becomes faster in running, it increases its Adaptability range. Thus, the development of mobility capability is a strategy in biological evolution. Professor Nick Lane stated, "Motion is a very fundamental and important invention" [5]. Professor Charles Marshall pointed out, "One outstanding change in the early evolution of animals was their actual locomotion ability" [7]. The ability to move can evolve to become stronger, with a wider range of motion, thereby expanding the adaptability range.

From the history of life, we can see that the evolution of organisms has generally developed towards stronger mobility and a larger range of action. Mobility is an important method for reducing the probability of extinction. According to paleontologists, there were two mass extinctions between 252.28 million and 252.10 million years ago. Before that, "the Paleozoic marine ecosystem was dominated by non-mobile animals," and afterward, "the Mesozoic and Cenozoic ecological structures dominated by mobile animals (ammonites, bivalves, gastropods, fish) began to appear" [8]. I speculate that these mobile species evolved from the organisms that survived the great extinction. This illustrates the benefits of mobility: mobile organisms are more adaptable than non-mobile ones. Fish in the water are said to have gradually developed organs that adapt to land, to acquire land resources, especially to obtain the radiant heat of the sun [9]. They then evolved into amphibians, expanding their choice of habitats. In the Cretaceous-Paleogene mass extinction, all non-avian dinosaurs and most avian dinosaurs went extinct; only one lineage of avian dinosaurs survived and evolved into modern birds [10]. This may also suggest that a wider range of mobility increases the likelihood of survival.

Therefore, the wider the Adaptability range of life, the more adaptable it is. Here, adaptability should not be understood as the precise fit of an organism's body structure to a specific point in the natural environment. Changes in the natural environment are frequent; to survive in such conditions, one must become adaptable to various environments. The wider the adaptability range, the more likely it is to survive. This is also the reason why biological evolution increasingly tends to expand the range of behavioral capabilities of organisms. Before the development of such behavioral capabilities, the main method for life on Earth to adapt to the environment was through changes in body structure or morphology. This change was extremely slow and often came at the cost of the mass extinction of many species. The so-called successful evolution is merely the accidental survival of a few lucky organisms that adapt to environmental changes amid widespread extinction. Therefore, the expansion of the behavioral range of organisms, and thus the expansion of the adaptability range, has a certain substitutable relationship with the strategy of "extinction and variation" in responding to environmental changes. From a long-term historical perspective, this substitution also brings a reduction in the costs associated with the response strategy. First, the number of individual deaths among species has been greatly reduced. Second, the probability of the emergence of new varieties is very low, and sometimes there may be no new varieties, leading to the extinction of the entire species. Even if new varieties do appear, they require a relatively long time to develop into mature body structures or morphologies. While expanding the Adaptability range of organisms requires additional energy expenditure—such as long-distance migration, which may consume a large amount of energy—and also involves dangers of death during the migration process, this loss is incomparable to the massive deaths caused by the inability to adapt to changes in the natural environment.

The degree of environmental change varies, with the most common being seasonal change. Organisms have adopted different strategies to adapt to this seasonal change. Herbaceous plants die in winter and regerminate from seeds the following year, while woody plants stop growth and shed their leaves in winter. Some animals thicken their fur or hibernate, whereas animals with strong mobility adopt the strategy of migration. The significant changes in the natural environment are the recurrent ice ages on Earth. For example, China has experienced four small ice ages in its history, with average temperatures 2.5 to 4 degrees lower than during warm periods. It is said that these ice ages triggered major changes in Chinese history and also affected the distribution of organisms at that time. When the ice age arrived, the northern regions became drier and colder. As a result, the northern nomadic tribes migrated southward, leading to conflicts between them and southern people, such as the rise of the Xiongnu in the north and their southward incursions during the Western Zhou dynasty. Similarly, we can imagine that mobile organisms could migrate to warmer regions to avoid extinction, and they would likely encounter opposition from the animals in those areas. Of course, in the face of significant natural environmental changes, the mobility and range of organisms at that time were insufficient to escape the harsh conditions, resulting in mass extinction. For example, 60 million years ago, the sudden temperature rise and subsequent cooling caused by the impact of a meteorite led to the near-extinction of the dinosaurs.

According to observations by biologists, in response to the non-periodic changes in the Earth's current environment, organisms have adopted the strategy of adjusting their living areas. "Currently, more than 30,000 cases of climate-driven habitat shifts have been observed and measured, involving various organisms, from dragonflies to foxes, whales, and plankton… Scientists estimate that 25% to 85% of all species are in the process of migrating" [11]. Especially in light of global warming in recent years, the migration of organisms has exhibited two trends: one is migration toward the poles, and the other is migration to higher altitudes [11]. Even within the same region, organisms can expand their Adaptability range by increasing the types of resources available. Omnivores, such as pigs, bears, some primates, and humans, can consume both plants and animals. Within the range of available food, they can even respond immediately to unexpected environmental changes, not only to avoid starvation but also to improve their diets. Biologists found that in the summer of 2014, "on Kodiak Island, Alaska… the bears abandoned the streams where they could catch salmon and turned to eating elderberries that ripened two weeks early." The reason was climate warming, which caused the elderberries to ripen earlier. Compared to salmon, bears prefer the protein-rich elderberries [11].

It is natural that improving behavioral capabilities and expanding the range of adaptability also require evolution. If this is an important strategy in biological evolution, then this evolution represents a significant aspect of it. First of all, the transition from immobility to mobility marks an important breakthrough. However, the biological community rarely provides examples of this type of evolution. Secondly, organs have evolved to become multifunctional. Although a biological organ is formed for a specific function, it can serve multiple purposes in practice. For instance, the fins of fish can not only propel them in the water but also allow them to move along the seabed. Similarly, the front limbs of chimpanzees can be used for climbing trees as well as for grasping. This results in a multifunctional organ. Once an organism possesses multiple functions, it is equivalent to having a range of mobility, enabling it to choose among these behavioral functions to adapt to different environments. This expands its Adaptability range. Furthermore, repeated selection of any one of these functions can enhance that particular behavior, making it more skilled and efficient, which will also increase mobility. For example, fish that use fins to walk on land, through the transition of true ray-finned fish, spiny salamander, and ichthyostega, gradually evolved into amphibians [9], facing a much wider habitat.

The improvement of biological behavioral capabilities can lead to both increased energy acquisition and higher energy consumption. Therefore, the condition for developing or expanding these behavioral capabilities is that the energy gained must continuously exceed the energy consumed in the process of acquiring more energy; in other words, there must be a more efficient use of energy. Thus, the prerequisite for enhancing behavioral capabilities is the evolution of more efficient energy acquisition methods and more effective energy utilization. This is also a crucial aspect of evolution itself. If organisms possess the ability to move, their foraging range will significantly increase, allowing them to obtain much more energy compared to those that are fixed or drifting with the flow. They will further expand their foraging area to gather more energy, which in turn supports their increased activity. This cycle continues until the marginal net energy benefit declines to zero, establishing the equilibrium range of a specific biological space. Improving the efficiency of energy acquisition involves changing the method of obtaining energy. Throughout the evolution from plants to animals, the method of energy acquisition has shifted from soil absorption or photosynthesis to direct intake, *i.e.*, "eating." This approach is much more efficient than photosynthesis and root absorption in terms of energy acquisition.

Between energy acquisition and energy consumption lies the efficiency of energy conversion, which determines the "cost" of existence for a living organism. In the evolution of animals, improvements in energy conversion and utilization efficiency depend on the specialization of the digestive system. For example, the simplest animals, such as amoebas and paramecia, digest food directly within their cells. "In sponge-like organisms, the intake and digestion of food mainly occur in cells with flagella that form food vacuoles and expel waste" [12]. This marks the beginning of specialized digestion. Gradually, in coelenterates such as hydra, extracellular digestive functions evolved. Later, stomachs appeared in organisms, serving as specialized organs for digestion. In higher animals, the digestive system became even more specialized, incorporating the small and large intestines, as well as a transport system that delivers digested nutrients throughout the body [12]. Clearly, the more specialized the digestive system, the higher its efficiency. Additionally, specialized respiratory systems, with lungs and hearts working together to convert oxygen and circulate energy-carrying substances throughout the body, represent a more advanced method of energy conversion and utilization.

In this process, there are also by-products that allow the biological action space to expand further. For example, some biologists suggest that the evolution of warm-bloodedness is a by-product of herbivory. To obtain nitrogen, herbivores consume large amounts of plants, which contain little nitrogen but a significant amount of carbon. "A strict vegetarian diet actually very easily creates warm-blooded animals because we have to constantly burn off a huge amount of carbon" [5]. This notion of "waste utilization" may seem overly negative; in fact, it represents another example of more efficient energy use. Once warm-bloodedness evolved, it facilitated niche expansion, nocturnal activity, adaptation to cold regions, and highly developed intelligence [5]. Most importantly, it increases "endurance." As Albert Bennett and John Ruben noted, "Animals with higher endurance have the following advantages: they can persistently search for food or flee from enemies; they also have an advantage in defending or seizing territory; they are also more likely to succeed in mating" [5]. This leads to improved behavioral capabilities, making the organism more adaptable.

We can use the range of mobility to distinguish different types of variation. Variant variation generally does not expand the range of mobility; it only changes the specific form of mobility. In contrast, upgraded variation typically improves mobility and expands the Adaptability range. Since variant variation remains within the original environment and its resources, it only enhances competitiveness in that environment. Its main form of competition is to produce more offspring than competitors. After multiple generations of replacement, its offspring will far outnumber the competitors, eventually leading to their extinction. This exemplifies the concept of "survival of the fittest". Upgraded variation, on the other hand, expands the space of behavioral capabilities. Although it results in significantly higher absolute energy efficiency than the original species and should be considered the absolute fittest, it also expands the Adaptability range of the organism. The upgraded variant species can forage in newly opened resource environments, avoiding direct competition with the original species, thus not hindering their continued survival. For example, while humans are much more efficient than chimpanzees, they no longer compete with them for food in the forest. This is why many upgraded variants exist on Earth, while the pre-upgrade species at various levels are also preserved.

The behavioral capabilities of organisms constitute their range of motion, which is their selection space. "Selection" means that they can arbitrarily choose a specific behavior within this selection space. The existence of a selection space implies that nature is not fixed in a certain state and cannot determine which specific behavior is most beneficial to an organism. Instead, nature provides a selection space and endows organisms with the ability to select adaptively, *i.e.*, the ability to judge the advantages and disadvantages of specific situations, allowing them to choose a behavior that achieves the most favorable result for themselves. Action must involve selection, and every step of action requires a choice. As Peter Ward says, "Motion is a behavior, and is itself a brain function" [7]. The improvement of biological behavioral capabilities and the expansion of the range of motion require organisms to make selections about which actions to take. Brain function is used for making these choices. Judging one behavior to be superior to others, or one point in space to be more advantageous than others, requires intelligence. Therefore, the expansion of an organism's range of motion and its Adaptability range is almost synchronized with the development of the brain.

3. BRAIN DEVELOPMENT AND SELF-SELECTION

When an organism evolves toward increased "mobility," the first problem is that if it moves blindly, it is equivalent to randomly changing its position, resulting in mixed benefits and drawbacks. We can assume that the organism's current location is similar to other locations, and the quantity of resources fluctuates randomly around an average. Therefore, other locations may be better or worse than the current one, with the probabilities being equal. Thus, "blind movement" is equivalent to "no movement" in terms of probability and offers no inherent advantage. If "movement" is to be superior to "no movement," then "selection" is required. The evolution of mobility can only be advantageous if it is paired with the ability to choose. However, developing the ability to choose is itself very difficult, which is why so many organisms remain in a non-mobile state.

If we view the range of behavioral capabilities as a set of behaviors, it represents the selection space of the organism. Discussing "selection" necessarily involves trade-offs, and there must be a goal: choosing the best behavior. What is considered the "best" is the most economical and energy-saving option. To choose the best, one needs the ability to judge. The ability to judge involves selecting the best option from various alternatives. This option provides the most benefit to the organism, meaning the least energy consumption and the greatest gain. This notion seems consistent with the assumptions of the economic person or rational actor in economics. Here, this ability to judge is not only possessed by humans but must also be present in all organisms with a behavioral capability space. Biologists say that the earliest brain emerged about 520 million years ago [13]. Before the emergence of the brain, many animals already existed, but since they were basically immobile, they did not need a brain, such as sea urchins, corals, jellyfish, and starfish. However, "in a world where we need to move, in order to adapt to rapid changes, we have evolved a brain" [13].

In fact, realizing selection within the behavioral space requires various prerequisites. First is the judgment of the environment, including the distance and direction of prey or predators, the temperature, and the speed of water flow or wind. This necessitates the development of sensory functions such as vision, smell, and touch. Not only does this require the development of the eyes, nose, or skin senses, but it also involves the brain's reception and interpretation of this sensory information to form an understanding of the environment, which can then serve as a reference for comparing various behavioral options. Of course, in the initial stages of brain development, these functions are still very weak. What we call the optimal choice is merely the choice made under the current capabilities of the brain. However, the brains of organisms at different levels should be adapted to their specific needs. For example, ants form effective societies; they can find food and detect enemies, and they have a clear division of labor in feeding the queen ant or patrolling outside. Biologists have documented the brain capabilities of other higher animals. No matter how primitive the brain is, as long as it can judge which of two or more options is better, that is sufficient. It does not have to be the optimal choice in the eyes of humans.

However, in the beginning, organisms did not know what kind of behavior would be most beneficial to themselves, because making a choice requires comparing various options and their results. Before any behaviors existed, they were unaware of the outcomes, so their initial choices might have been random or could be described as random variations of behavior. However, when a particular behavior, by chance, produced a favorable result, and the organism realized that this result was related to that specific behavior, it would repeat that behavior the next time it encountered a similar situation. In this way, each time it faced a similar situation, it would choose the same specific behavior. Therefore, the brain's choice is not about finding a better place or behavior, but rather about the ability to judge the pros and cons of the outcomes of random behaviors. Without this ability, even if the initial random choice happened to be correct, the inability to discern its consequences would result in missed opportunities. Moreover, a successful mutation not only requires stumbling upon the right mutation but also the ability to persist with that mutation. With such a choice, the probability of upgraded variation is significantly increased. Although this can be judged by the direct experiences of organisms, the results of some behaviors are not immediate; they can only be revealed after several causal chains, which requires the brain's discriminative ability.

This ability of the brain to make judgments involves comparing the consequences of a certain behavior with the benefits and drawbacks to the organism's survival and evaluating its value. Of course, the level of this ability in brains of different species is not the same, with some evaluations being more accurate and others less so. Regardless of whether the brain's evaluation is right or wrong, it ultimately must be verified by natural selection. Therefore, the organism's use of the brain to choose increases the probability of making the right choice rather than guaranteeing that it will always be the right choice. Each of its behavioral choices will yield a result from nature, and the brain will adjust these choices based on the outcomes, gradually approaching the correct one. It is only through this combination with natural selection that evolution is completed. However, compared to random variation and the accidental persistence of variation, the brain has indeed increased the probability of successful evolution. Of course, to maintain good behavior, it is essential to remember the positive outcomes of such behavior, which requires memory. This memory aids in adjusting and enhancing the brain's ability to make value judgments. Ultimately, behavior is controlled by the brain; it can rapidly act on various parts of the body through nerve cells [13]. Therefore, the choice of behavior is a complex process, and the development of the brain is crucial for its execution.

We can confidently assert that choices made through the brain are superior. This is the economic man hypothesis in economics, where people will rationally choose the behavior that is most beneficial to themselves. This principle can also be extended to all organisms with a brain. The terms "best" or "most beneficial" are not determined by external human judgments but by the organism's own assessment, which is governed by its brain. As mentioned earlier, as long as an organism can evaluate which of two or more options is better, it can improve its behavior. Darwin described animals with psychological abilities lower than those of humans. He believed that while the intelligence of these animals differs from that of humans, it is not fundamentally different. He observed that animals possess varying degrees of attention, memory, imagination, and reasoning abilities, citing examples of an elephant and a bear using intelligence to obtain objects [14]. Therefore, we have no doubt that the function of an animal's brain is to enable it to make better choices.

Moreover, the animal's brain has evolved in response to its living environment, becoming optimally adapted for that specific context. In this regard, their brain efficiency may surpass that of seemingly more advanced animals. Biologists conducted an experiment, placing food on both red and blue plates, and removing the red plates after two minutes. "The six adult splitfin fish who participated in the experiment all learned to eat the food from the red plate first, with the learning process averaging only 45 trials. In contrast, only 2 out of 4 chimpanzees were able to solve this problem within 100 trials (60 and 70 trials, respectively). The remaining 2 chimpanzees, along with all the gibbons and capuchin monkeys, failed to learn to eat the food from the red plate first" [15]. The biologists explained that splitfin fish live in the wild, while the primates used in the experiments were captive; the splitfin fish must fend for themselves, making them skilled at it, "and it has nothing to do with brain capacity" [15]. I would add that the range of motion for fish is narrower than that for primates, so their brains are specialized to handle this more limited domain, similar to specialized computer chips. In contrast, primates have a broader range of motion, and their brains manage a wider array of situations, akin to general-purpose computers.

It should be noted that the brains of different individuals within a single species may vary significantly. Their choices also differ. This is equivalent to a group conducting multiple exploratory choices simultaneously. Especially at the beginning, this random variation in individual choices clearly increases the chances of discovering more optimal behaviors. Some individuals' more accurate choices will lead to better outcomes. This relationship between behavior and outcomes will be observed by other individuals in the population, who will imitate these successful behaviors for their own benefit. This constitutes a choice—one based on the results of existing diverse behaviors—which can be termed **second-order selection**. Through such choices, individuals in a population tend to converge toward optimal choices. As a result, the energy efficiency of this biological group improves, placing it at a competitive advantage against other groups of the same species. Alternatively, this tribe can exclude other tribes through peaceful competition or even eliminate them; or, the other tribes can learn from the superior behavior of this leading tribe and enhance their energy efficiency. Thus, that optimal behavioral choice spreads throughout the species. However, this is still an extension of brain choice, achieved through observation, communication, learning, and imitation of other individuals or groups. This still requires the decision-making capabilities of the brain. Therefore, the "self-selection" mentioned here refers not only to the choices made by individual organisms but also to the choices made by groups or societies, which accelerates the discovery and dissemination of optimal choices.

Once an organism has made the best behavioral choice and is aware of it, the next step is to repeat that choice. Since it is the most beneficial behavior for itself, there is no need to deviate from this behavior; only through continuous repetition can it obtain sustained benefits. This long-term persistence in the correct behavioral choice will ultimately lead to upgraded variation. This can only occur if there is a driving force that compels the organism to persist in the long term: survival. The choices of the organisms that survive are the best. The so-called "best" refers to the most economical choice under the current natural environment. Many observations show that organisms choose behaviors that are most beneficial to their survival. For example, plant roots will extend toward the direction of water sources [16]. However, compared to humans, the economic nature of other organisms is relatively crude. Nevertheless, if they can survive, their choices are correct; those individuals whose choices are wrong will cease to exist. Furthermore, they can only continue to survive by persisting in this economic behavior, and long-term repeated behavior becomes a habit, which they will also teach to their offspring, thereby becoming a tradition.

Of course, even if an organism has chosen the right behavior, it still takes a long time for the ultimate development and upgraded variation to occur. There are also some intermediate stages in between. We also need to note that upgraded variation, compared to variant variation, is a more far-reaching and revolutionary change. This kind of variation is obviously not caused by a single random chance variation, nor can it be completed in a few generations. It may require continuous evolution in the same direction for hundreds or even thousands of generations [17]. The long-term persistent repetition of a specific behavior, leading to effects of use and disuse, is another important path of evolution. "Use" means action, taking specialized, specific actions repeatedly; "evolution" refers to the bodily changes caused by repeated actions, making it adapt to this action. For example, the behavior of bipedal walking in hominids has produced a body adapted to upright walking, and the frequent use of intelligence has increased brain capacity. The reason for "the evolution driven by use" is action. And action is the self-selection of the organism, or the selection of those who accompany it. When an organism makes a choice, it must choose the behavior that is most beneficial to it. Viewed in this way, this variation is caused by conscious or motivated behavioral choices. The reason why "the evolution driven by use" works is not random selection, but repeated selection, or in other words, the organism's self-selection. If this is the case, **an important path of the economic evolution of organisms is the self-selection of organisms**.

Among the various behavioral choices, organisms ultimately choose between two behaviors. There are generally two types of relationships between these behaviors: substitutable and complementary. Substitutable behaviors are those where the implementation of one can replace another to achieve the same or similar purpose. For example, animals can either run quickly or hide when escaping; running and hiding are two substitutable behaviors related to escape. Similarly, digging holes with either the mouth or forelimbs represents two interchangeable behaviors aimed at creating an underground nest. Complementary behaviors, on the other hand, are those where one behavior helps or promotes another. For instance, using the brain to make judgments can assist the limbs and teeth in more effectively capturing prey. Organisms self-select the more effective behavior from the substitutable options. The chosen behavior is practiced repeatedly, leading to "use," while the replaced behavior results in "disuse." Among the various complementary behaviors, selecting those with greater complementarity will lead to more frequent repetition of the chosen behavior, which in turn promotes the repetition of the behaviors it supports, all resulting in "use".

When organisms follow economic principles to make choices, they are selecting one from a set of alternative options, which may seem to narrow down the behavioral space. However, actual evolution shows that when organisms choose the better or optimal behavior, and if evolution occurs according to the "use or disuse" rule, they often face an even larger choice space. For example, when fish chose walking over swimming with fins, their evolution into amphibians increased their choice space on land; when hominids chose upright walking over tree climbing, they encountered a broader range of hand-related behaviors. Of course, this takes time. That is to say, the rational, economic selections of organisms, although they represent one of the behaviors in the original choice space, contain great potential. After undergoing a developmental and evolutionary process, their behavioral choice space becomes even larger. A larger choice space means that the alternative options included are more likely to contain better choices. In the long run, the trend of multiple upgraded variations is to continually expand the choice space of organisms. This means that the behavioral choice space formed after multiple upgraded variations originates from one behavioral choice in the initial basic choice space; in form, it belongs to this basic choice space, but it is larger than the basic choice space that generated it. This indicates that the optimal behavioral choice also has the property of expanding the choice space. Thus, the self-selection of organisms through the brain has a tendency to progressively amplify the choice space, and the larger choice space may contain even better behavioral selections.

Of course, when we refer to the "best" behavior chosen by organisms through self-selection, it is the "best" based on their brain capabilities, not from a God's-eye view. Their brain capabilities vary greatly and may even be relatively poor. However, the final arbiter in assessing the quality of an organism's self-selection is natural selection. "Better" choices will achieve higher energy efficiency and thus a greater probability of survival, while "poorer" choices will have a lower probability of survival. The level of "energy efficiency" depends on the operating efficiency of the organism's body and its adaptation to the natural environment. If an organism unfortunately chooses a very poor behavior that cannot sustain its survival, natural selection will eliminate it. However, self-selection is not opposed to natural selection; it is simply different from random variation. Through the rational selection of behaviors by their brains, organisms tend to evolve toward higher energy efficiency. Although there may still be some failures, the probability of making a successful choice is much higher.

Therefore, the self-selection of organisms has a higher probability of achieving successful evolution compared to random gene variation. This is reflected in the history of life, where the intervals between upgraded variations through self-selection are shorter, the choice range of organisms becomes wider, and they become more adapted to the changing natural environment. This evolutionary strategy is increasingly replacing the mode of random selection and mass extinction.

3.6 billion years ago, the oldest life forms—cyanobacteria—appeared; 2.2 billion years ago, eukaryotes were born; 560 million years ago, multicellular organisms emerged; 500 million years ago, fish appeared;

390 million years ago, amphibians emerged; 320 million years ago, reptiles appeared; 300 million years ago, mammals emerged; 140 million years ago, birds appeared; 66 million years ago, primates emerged; and 6 million years ago, humans appeared [18]. Upgrades seem to be accelerating. This is likely related to the fact that organisms can self-select, and the choice space continues to expand. Self-selection—rational selection—means that organisms seize better-than-chance behavioral choices and persist in them, which increases the probability of upgraded variations.

4. HOW IS EFFECTS OF USE AND DISUSE ACHIEVED?

Although modern Darwinists emphasize that variation is random, Darwin himself did not attribute the cause of variation solely to random factors. In ***The Origin of Species*** and ***The Descent of Man, and Selection in Relation to Sex***, he mentioned the effects of use and disuse, treating them as one of the laws of variation. Darwin found that the legs of domestic ducks are thicker than those of wild ducks, while their wings are smaller, because domestic ducks walk more and fly less. He also noticed that the mammary glands of cows become larger due to frequent milking and observed that these variations are inheritable. In Chapter 5, "Laws of Variation," of ***The Origin of Species***, Darwin specifically discussed the "effects of use and disuse," stating that in different natural environments, the use or disuse of organisms' organs leads to evolution. For example, the eyes of mole-like burrowing animals are underdeveloped or even completely blind [2]. He noted, "The ostrich indeed inhabits continents and is exposed to danger from which it cannot escape by flight, but by kicking it can defend itself from enemies, as well as any of the smaller quadrupeds. We may imagine that the early progenitor of the ostrich had habits like those of a bustard, and that as natural selection increased in successive generations, the size and weight of its body, its legs were used more, and its wings less, until they became incapable of flight" [2].

This evolutionary law of use and disuse was also employed by Darwin to explain human evolution. In ***The Descent of Man***, he discussed the reduction of human body hair, the inability of the skin to move, the inability to move the ears, and the decline in the sense of smell, relating these changes to the long-term disuse of these organs in accordance with the law of "disuse". Regarding "use," in the section "Effects of the Increased Use and Disuse of Parts," Darwin cited examples such as the obvious physical differences between U.S. sailors and soldiers, noting that "the hands of English laborers are at birth larger than those of the gentry," "watchmakers and engravers are liable to be short-sighted," and that the Quechua Indians "have acquired chests and lungs of extraordinary dimensions" due to living in the thin air of the highlands. He stated that "whether the several foregoing modifications would become hereditary, if the same habits of life were followed during many generations, is not known, but it is probable" [14]. He further inferred that "when at a remote epoch the progenitors of man were in a transitional state and were changing from quadrupeds into bipeds, natural selection would probably have been greatly aided by the inherited effects of the increased or diminished use of the different parts of the body" [14].

Clearly, the two major differences between humans and their closest ape relatives are upright walking and expanded brain capacity. These two significant variations were likely the result of "use"—the repeated use over many generations. According to some anthropologists, upright walking uses only 25% of the energy required for quadrupedal locomotion. By walking on their feet, the front limbs—the arms—were liberated, allowing humans to perform various actions, whether for hunting or foraging, greatly improving efficiency. They could also manufacture tools, thereby increasing their efficiency by an order of magnitude. As humans adopted more complex behaviors, their brains gradually became more complex and larger. This development made humans more intelligent, enabling them to create various technologies and institutions to enhance their efficiency. Darwin explained this using the logic of the struggle for existence: different behaviors lead to victory or defeat in competition. He noted, "in the rudest state of society, the individuals who were the most sagacious, who invented and used the best weapons or traps, and who were best able to defend themselves, would rear the greatest number of offspring. The tribes, which included the greatest number of men thus endowed, would increase in number and supplant other tribes" [14].

Better technology represents a more optimal behavioral choice, ultimately leading to the replacement of one tribe by another. As Darwin stated, "the intellectual and moral faculties of man… are variable; and we have every reason to believe that the variations tend to be inherited" [14]. Intelligence and morality are both enhanced as the brain develops, enabling humans to make self-selections that lead to more effective behaviors. This use of the brain itself is also a behavior that improves its capacity and function because it benefits the user. Clearly, the brains and corresponding rational and moral functions of the victorious tribes will further develop. In this process, the repeated and continuous use of the brain, the ongoing exploration of new technologies, and the reinforcement of moral behaviors are crucial. This continuously repeated behavior is termed "habit". Darwin often used this term when explaining the "effects of use and disuse." From an economic perspective, habit is the behavior that the actor currently considers the best choice and does not need to change, which also saves the actor's decision costs. However, habit is not instinct. Darwin noted, "the more the habits of any particular animal are studied by a naturalist, the more he attributes to reason and the less to unlearnt instincts" [14]. Therefore, habit is the repeated behavior chosen by the brain.

Later biologists and anthropologists often use changes in human behaviors and the formation of these behaviors into new habits to explain the evolution of bipedal upright walking and the increased brain capacity of humans. For example, "the evolutionary direction from facultative bipedalism to habitual bipedalism can be confirmed in most ancient human species" [19]. Once bipedal walking became a habit, the human activity radius expanded, hands were freed; human groups grew larger, social needs increased, and the human brain gradually enlarged. "From the emergence of habitual bipedalism to the hominization process, the selective pressures were very strong, not only promoting our brains to become larger, our spines to become S-shaped, our legs to become longer, our arms to become shorter, and our pelvis to become narrower, but also restructuring our digestive system and cognitive abilities. The novel development of the brain led to a complete reconstruction of human physiology and behavior" [19]. One study found that "the longer taxi drivers spend on the job, the larger the posterior part of their hippocampus becomes," because they have to remember information about thousands of roads and locations [20]. This explanation attributes the cause of variation to use and disuse. The most important variation is the significant increase in brain capacity.

From the perspective of the history of life, this habitual behavior is not only the behavior of individual organisms but also the conscious persistence of populations over millions, tens of millions, or even hundreds of millions of years. For example, the evolution of fish into amphibians was likely due to the continued use of fins to move on land. It took about 15 million years for "true ray-finned fish to evolve all the basic skeletal features necessary for life on land" [18]. The evolution from theropod dinosaurs to birds took about 150 million years [10]. The tripling of human brain capacity from 7 million years ago to 300,000 years ago, marked by an accelerating growth process, is clearly the result of continuous variations over several million years, as humans have consistently used their brains more. We can imagine that these major upgraded variations also underwent a process of continuous self-selection by the organisms. This process is extremely long. Of course, we can speculate that this process can be divided into multiple stages, each with stage-specific achievements, such as the development of the sternum, changes in leg bones, the transformation of the beak, the appearance of wings, and the formation of tail feathers in the evolutionary process of birds. All of these gradually became more conducive to flight and arboreal life.

Modern "orthodox" evolutionary biologists deny the role of use and disuse, asserting that biological evolution relies solely on random genetic variation. The phenomena that appear to be related to use and disuse occur because random genetic variations happen to be adapted to the changed environments of the organisms. For example, random genetic variations in domestic ducks that are not suited to their behavior and environment will be eliminated, while those that happen to be advantageous will be retained. Even if this argument holds, it does not negate the role of domestic ducks' preference for increased walking behavior in natural selection. A certain habitual behavior can also be considered a form of "nature." When random genetic variations are beneficial to this habitual behavior, they are accepted and consolidated because they align with this "nature"; in contrast, variations that do not support this habitual behavior are neither accepted nor consolidated. In this context, the likelihood of genetic variations evolving in a direction that benefits that behavioral habit is higher than in cases where such a behavioral habit has never existed.

Therefore, the formation of a particular behavioral habit will still influence the direction of genetic variation and accelerate its speed. Another example is that Matt Ridley found the ability to digest milk is strongest in ethnic groups with a history of pastoralism. He pointed out that to adapt to the pastoralist lifestyle, "they evolved the ability to digest milk, rather than discovering they had the milk-digesting gene and choosing to be pastoralists on the grasslands." He then inferred that "genes can change according to need, can change through free will, and can also be influenced by conscious behavior" [21]. This logic applies to more general cases.

However, neither Darwin nor those who later inherited the theory of use and disuse seem to have explained how use and disuse affect variation. Even Lamarck, who is often seen as a proponent of the effects of use and disuse, did not clarify how this variation occurs. Modern neo-Lamarckists have developed the field of epigenetics, but they do not appear to have specifically addressed this point. Epigenetics primarily discusses organisms' stress responses to sudden changes in the natural environment, especially natural disasters. These stress responses affect the methylation of genes, activating or suppressing the functions of certain genes, which can lead to phenotypic changes in the organism. This activation or suppression of genes can also be inherited by offspring. For example, the descendants of soldiers returning from the battlefield exhibit a higher incidence of homicidal behavior than the average population [7].

However, the so-called impact of the natural environment is manifested in the relationship between the natural environment and the biological subject, embodied in the feelings of the biological subject. This impact depends on the circumstances of both parties. For example, when fish choose to use their fins to crawl more on land, their environment gradually changes from aquatic to terrestrial; similarly, when chimpanzees choose to walk more upright, their environment transitions from forest to grassland. Therefore, behavioral choice is also a form of environmental change. This change is not sudden but rather gradual and progressive. According to epigenetics, this behavioral change may also affect the attachment of small molecules to genes, leading to their activation or suppression. Regardless of how minor this effect may be, it challenges the theory of random genetic variation, as this change is no longer random.

The difference between changes caused by self-selection and those caused by changes in the natural environment lies in the fact that the former involves the choices of individuals within the same natural environment, which can differ from the choices of other individuals. If this self-selection is more optimal, it will certainly prevail and establish a better relationship between the biological subjects and the environment. In contrast, changes in the natural environment affect all biological individuals equally. Some individuals may simply be better adapted to these changes without consciously choosing better coping behaviors. Therefore, the self-selection of biological subjects carries a certain degree of initiative. More likely, in the absence of changes in the natural environment, biological subjects actively alter their behavior to acquire energy more effectively. For example, primitive humans discovered that they could hunt large animals more efficiently by cooperating with one another than by hunting individually. This is akin to the environment becoming more abundant. The changes in the relationship between the biological subjects and the natural environment brought about by self-selection may also affect the methylation of genes, alter phenotypes, and ultimately impact the genes themselves. Since genes can respond to sudden changes in the natural environment by turning their functions on and off, they should also be able to continuously adjust their functions in response to persistent and lasting behavioral changes.

The epigenetic perspective suggests that these small molecules themselves are not inherited; rather, what is inherited are the sites that can be easily attached by these small molecules. We can also consider that genes have their own selection space within which they can make choices. This can be viewed as the heritability of the activation or deactivation of genes triggered by behavior. This aspect can partly align with the behavioral choices of the organisms themselves. The rules of nature dictate that organisms are given a selection space, allowing them to choose the behaviors or physical structures that best suit them. While physical structures may appear to be fixed, nature cannot guarantee that they are necessarily the most suitable for survival. The optimal physical structure or behavior can only be discovered through exploration by the organisms themselves. To facilitate this exploration, nature provides them with a certain selection space and the ability to choose—namely, the brain. This is a flexible arrangement in accordance with the principle of optimality. Similarly, evolution itself is fraught with risks and should not be decided in a single stroke. The evolutionary process must also be a flexible transitional process, capable of correcting errors that arise during evolution. Therefore, the findings in epigenetics regarding methylation, histone modifications, and small RNA molecules that inhibit or activate genes represent different responses to various contexts without altering the genes themselves [7], showcasing the flexible characteristics of the evolutionary transitional process.

The fact that genes can inherit their methylation sites means that they are also inheriting their choice space. When a certain behavior is repeatedly performed in a long-term environment, the gene's preference for this behavior will be further strengthened. It can be speculated that the behaviors and choice spaces of an organism are originally confined within the range of body structures and functions determined by the existing genome. Repeated behaviors continuously activate the corresponding genes, and the positive outcomes resulting from these behaviors encourage and reinforce the associated genes, making them the normal state of the genes. In contrast, the functions of other long-unused genes remain long-term shut down, and their disuse becomes the normal state of the genes. This ultimately manifests as genetic variation, internalizing the repeatedly performed behaviors into genetically determined behaviors and causing changes in body structures that are favorable to those behaviors. These changes will be inherited along with the genes.

If we acknowledge that the self-selection of organisms is a form of "rational selection," and that rational selection involves selecting the more optimal behavior between two options or choosing the most optimal behavior among various options, then "more optimal" or "most optimal" refers to higher or the highest energy efficiency. Furthermore, if this direction of self-selection by organisms has remained consistent for hundreds of millions of years, we can conclude that organisms evolve toward a more economical direction. It is undoubtedly true that the upgraded variations of organisms through self-selection possess an economic nature.

5. CONCLUDING REMARKS

In summary, the essential nature of biological evolution is economy, specifically the significant improvement in the energy efficiency of organisms. This is primarily manifested in upgraded variations that are distinct from varietal variations. If biological evolution solely relies on random genetic variations, and its success or failure depends only on whether it adapts to the natural environment, then the highly revolutionary and transformative upgraded variations seem very difficult to occur and persist. Random genetic variations can only lead to minor variations—those that happen to adapt to changes in the natural environment, often at the cost of the extinction of the majority of similar species.

Another evolutionary strategy is to increase the mobility and spatial range of organisms to expand their adaptability, allowing them to adjust their behavior in response to certain changes in the natural environment. Therefore, a larger adaptability range means greater adaptability. When organisms possess a certain behavioral capability, they will have a choice space and will choose the behaviors that are more beneficial to themselves. Choice requires a brain; thus, as behavioral capabilities improve and adaptability ranges expand, the need for choice increases, leading to further brain development. The behavior that organisms choose through their brains, which is beneficial to themselves, is their self-selection.

Once organisms have chosen the behaviors that are more beneficial to themselves through trial and error, continuing to repeat these behaviors will remain advantageous, leading them to persist in them. Thus, the behaviors that are performed repeatedly will become habits. Persistent habits will produce the effect of "use and disuse", meaning that repeatedly using an organ will cause it to develop and grow, while long-term disuse will lead to atrophy or abandonment. Major upgraded variations occur based on sustained behaviors over an extremely long period, lasting from several million to tens of millions of years. In this process, it is possible that first, epigenetic changes occur, where repeated behaviors lead to the continuous activation of corresponding genes, while the long-term lack of a behavior results in the prolonged suppression of those genes. This ultimately leads to changes in the genes themselves, which then cause corresponding changes in body structure, completing the upgraded variation. Since this variation originates from self-selection based on economic rationality, the upgraded variation is, therefore, economic.

Finally, when we recognize that biological evolution has a general economic nature and largely depends on the rational choices of organisms, we can envision that applying economic methods to the analysis of biological evolution may open up new research directions and potentially yield fruitful results. Overall, economics can serve as a unified method for biology. For example, we can use the economic theory of specialization to understand the trend of specialization in biological evolution and to comprehend why specialized integration is superior. We can also apply the concept of economies of scale to understand the evolution of large organisms and use the theory of enterprise boundaries to explain why organisms are not always better off being larger, *i.e.*, why there are still so many small organisms. Furthermore, for the many different species that exist in the same natural environment, we can view them as different survival strategies within that environment; we can use economic perspectives to examine them as diverse life models. Using the more formalized characteristics of economics, we can analyze biological evolution in a more mathematical and quantitative manner. Conversely, the analysis of biological evolution may also stimulate further development of economic methods to better accommodate analysis of biological evolution.

From another perspective, economics is adept at analyzing "rational selection". According to the framework of this article, rational selection is one of three types of choice—random selection, rational selection, and natural selection—which together constitute a complete method for cosmic evolution. Introducing economics into this comprehensive method can enhance and strengthen the explanation of cosmic evolution; therefore, it serves as an important approach for biology and even cosmology, as well as an epistemological method for understanding the universe. It can also become a significant component of the epistemology of artificial intelligence.

In this context, natural selection serves as the ultimate arbiter of the correctness of choices. While random selection may accidentally favor behaviors that meet the conditions of natural selection with an extremely low probability, rational selection attempts to align behavior as closely as possible with the standards of natural selection within the bounds of rationality. Generally speaking, rational selection (*i.e.* self-selection) will be superior to random selection. However, due to the limitations of rationality and the vastness of the space of natural selection, rational selection may either exclude the optimal choice or require a rational process that is too complex and costly to implement effectively. In such cases, the success rate of random selection may be higher. The conclusion is that organisms should strive to use their rationality as much as possible but should not dismiss random selection; ultimately, natural selection should be the final arbiter.

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CONFLICTS OF INTEREST

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