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Stability-Based Sorting

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Synonyms

Natural selection through survival alone; Persistence principle Persistence through time of a lineage; Selection for thermodynamic stability; Selection of long-lasting structures; Selection on persistence; Sorting for stability; Sorting on the basis of stability; Survival in the existential game; Viability selection

Definition

Stability-based sorting (SBS) is a universal evolutionary mechanism that fosters traits contributing to the enduring existence of their bearers. This process, applicable to all material and immaterial entities, does not necessitate these entities to reproduce or exhibit heredity. In any system, it invariably results in the accumulation of entities that vanish at the slowest rate.

Introduction

Stability-based sorting (SBS) represents a fundamental evolutionary mechanism that influences the characteristics of systems and their constitutive entities based on their stability. Unlike natural selection, which operates on the principle of differential survival and reproduction, SBS does not necessitate entities to reproduce or exhibit heredity. Instead, it operates on the principle of persistence, favoring entities that are stable and endure over time. In essence, entities that are stable persist, while unstable ones disappear or transform into something else. This article delves into the concept of SBS, its history, and its comparison with natural selection. Examples of SBS in various contexts, such as the evolution of ecosystems and the universe, the predominance of sexual reproduction, solidification of institutions, the political stalemate in established communities, and the competition between democratic and non-democratic systems, are explored. The unique advantages of SBS, including its ability to "see ahead" and evolve traits ensuring long-term success, are examined. The entry provides a comprehensive understanding of SBS and its pivotal role in shaping the world.

History

The principle of stability-based sorting (SBS) found its application in evolutionary biology even before the principle of natural selection, as

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it underlies the proto-evolutionary ideas of Empedocles of Akragas. Empedocles, an ancient Greek philosopher and poet (born around 490 BCE, died around 430 BCE), claimed that the Earth had given birth to living creatures, but the first creatures had been disembodied organs (Campbell, 2000). These organs eventually joined into whole organisms. However, many of these organisms, being monstrous and unfit for life, had died out. This concept can be seen as an early form of SBS, where entities that were not stable enough to survive and reproduce effectively disappeared, while those that were stable persisted.

Over the years, several concepts related to SBS have been proposed in various fields. Researchers have called SBS by different names depending on the context. For example, it has been referred to as sorting on the basis of stability, sorting for stability, survival in the existential game, persistence through time of a lineage, selection for thermodynamic stability, selection of long-lasting structures, natural selection through survival alone, viability selection, selection on persistence, and persistence principle (for review see Toman & Flegr, 2017).

The concept of SBS was reintroduced into modern evolutionary theory by Elisabeth Vrba and Stephen Jay Gould (1986). They demonstrated that some characteristics of living organisms might not have evolved due to selection, but due to sorting. This was a significant shift in understanding, as it suggested that not all traits in an organism necessarily confer a selective advantage; some might simply persist because they are stable.

Recently, Toman and Flegr (2017) have brought new insights into the role of stability-based sorting (SBS) in evolution. They demonstrated that natural selection is a special case of SBS, specifically a case of sorting based on dynamic stability rather than static stability. The criterion for dynamic stability is the magnitude of the difference between the rate of generation and expiration of a given entity, while the criterion for static stability is solely the rate of expiration of a given entity. However, in this article, I use the term stability-based sorting (SBS) in its original narrow sense, i.e., sorting based on static stability. Toman and Flegr also showed that SBS plays a crucial role in the evolution of a specific category of traits. These traits are distinct from those that emerge through selection. Specifically, they highlighted the role of SBS as a pivotal process in macroevolution.

Differences Between Selection and Stability-Based Sorting

While both selection and stability-based sorting (SBS) are fundamental processes in evolution that significantly influence the direction of transformation of living organisms, they operate on different principles and have different requirements. Moreover, the traits of organisms that arise under their influence are quite distinct.

Selection, which includes, e.g., natural selection in the strict sense, sexual selection, parental selection, and artificial selection, operates on the principle of differential survival and reproduction. Any form of selection requires the selected entities to exhibit variation in traits, with different forms of the trait affecting the probability of survival and reproduction of corresponding entities differently. Crucially, selection requires heredity: offspring must inherit the form of the trait carried by its parent(s). The operation of selection leads to the accumulation of beneficial traits over generations and to the gradual increase in the utility of these traits for the survival and reproduction of their carriers.

On the other hand, SBS operates on the principle of competition between any entities in terms of stability. The principle of this competition is simple – stable entities in the environment persist, while unstable ones disappear or transform into something else (and thus also disappear). Unlike selection, SBS does not require entities to exhibit any heredity or a parent-offspring relationship. Individual entities can arise completely independently of each other, similar to the formation of snowflakes in clouds. As a result, SBS favors characteristics that increase the persistence of their holders, leading to the accumulation of stable entities in any evolving system. SBS can act on all entities, biological and abiological and material and immaterial (like ideas), regardless of their nature, origin, or the presence or absence of heredity (Toman & Flegr, 2017; Vrba & Gould, 1986).

Examples of Selection and Stability-Based Sorting

An example of selection in the biological world can be seen in the parental selection among nidicolous bird species (Lyon et al., 1994). Parents that return to the nest with food are more likely to feed offspring with conspicuously colored gape (the interior of an open mouth), compared to those with less conspicuous gape. The more frequently fed offspring grow better, are stronger, and more viable in adulthood and therefore will have more offspring of their own than those with less conspicuous gape. Their offspring, in turn, inherit the conspicuous gape. Among them, individuals with even more conspicuously colored gape are found, and they prosper best of all. Over the course of evolution, the gapes of these birds become increasingly conspicuous, often brightly colored, and are externally bordered by contrastingly colored edges. From the perspective of parental selection, such coloring is advantageous, but from the perspective of the environmental component of natural selection, it can be harmful as it may more easily attract predators.

In the realm of non-biological systems, an example of selection can be seen in the evolution of automobiles or mobile phones. Individual manufacturers compete with each other for customer favor, with new models introduced to the market by a certain manufacturer being similar in many respects, as within a company, production resources (machines, factories) and especially know-how, concepts, and patents are "inherited." During this competition, successful manufacturers prosper and unsuccessful ones disappear, and as a result, automobiles (or mobile phones) gradually improve.

As examples of systems primarily evolving under the influence of SBS, we can mention the development of ecosystems, the dominance of sexually reproducing species on Earth's surface, and the evolution of the universe (Flegr, 2022).

The development and succession of ecosystems at all levels, including the competition of biomes, is primarily (though not exclusively) driven by SBS. Ecosystems that are more stable and resilient to environmental changes are more likely to persist over time, while less stable ecosystems may collapse or transform into other ecosystems. This stability can be influenced by a variety of factors, including biodiversity, resistance to abiotic disturbances, resilience to the arrival and establishment of invasive species, and the ability to rapidly colonize vacant habitats or displace existing ecosystems from occupied habitats. Over time, the process of SBS can lead to the accumulation of stable, resilient ecosystems. This process occurs during succession at individually locally delimited habitats and concludes with the climax stage.

It's important to note that while the competition of biomes is evident at the level of local communities, it also has implications on a much larger scale. In the past, the biosphere has experienced many catastrophic events, during which most of the species living at the time went extinct. Over the last 500 million years, i.e., in the Phanerozoic for which we have a well-mapped record of the biosphere's development, the intensity of extinction has gradually decreased, and a progressively smaller proportion of species have gone extinct during disasters (Newman & Sibani, 1999). It's possible that the observed direction of Earth's ecosystem evolution is due to external causes, such as the scale of incoming disasters being smaller than in the past. However, another plausible explanation could be that this is a result of stability-based sorting (SBS). Groups of species, taxa, or ecological communities that were prone to extinction have already gone extinct, and over time, taxa and communities resistant to disasters have prevailed.

SBS may also be the reason why among the described eukaryotic species today, species reproducing sexually far outweigh. This is despite the fact that sexual reproduction is disadvantageous in many respects and that within a sexual species, in the vast majority of taxa, asexual lineages (or lineages capable of alternating sexual reproduction with asexual) can easily arise and should theoretically be able to displace the exclusively sexually reproducing maternal species. There are many theories that promise to explain the predominance and long-term maintenance of sexuality by natural selection, but most of them are not even remotely satisfactory, and the proposed mechanisms can only operate under narrowly defined conditions (Maynard Smith, 1978). It is therefore possible that the predominance of sexuality is the result of sorting in terms of stability.

Sexually reproducing species have a fundamentally limited ability to adapt to changed conditions compared to asexual ones. Surprisingly, in randomly fluctuating conditions, i.e., in conditions that prevail in most environments on the surface of the Earth, this apparent handicap can be a decisive advantage. An asexual, evolutionarily plastic species generally prospers more for most of the time than a species with sexual reproduction exhibiting limited plasticity, as it has the ability to adapt to the current conditions. Sooner or later, however, it will adapt to conditions that have deviated in a random and short-term manner, and when the conditions return to their original state, it will become extinct before it can adapt to these restored conditions (Williams, 1975). Computer simulation has shown that due to this phenomenon, a sexual species displaces an asexual species in a wide range of conditions differing in the frequency and amplitude of cyclic or acyclic changes in environmental conditions (Flegr & Ponížil, 2018). In the competition between sexual and asexual species within the variable environments that dominate most of the Earth's surface, selection that maximizes the fitness of organisms is not the decisive factor. Instead, the sorting based on stability is. In stable environments, which exist in many kilometers of the Earth's crust, it is likely that asexual species will prevail.

The evolution of the universe can also be seen as a process of SBS (Flegr, 2022). Over billions of years, stable structures such as certain types of elementary particles, stars, and galaxies have persisted, while less stable structures, regardless of how common they were in the early stages of the evolution of the universe, have disappeared or transformed into something else. This process is governed by the laws of physics, which dictate the stability of different structures based on factors such as mass, energy, and gravitational forces. For example, only stars that have internal dynamics regulated by some kind of negative feedback (the nature of which differs in different classes of stars), and therefore do not explode or burn all their thermonuclear fuel immediately after their formation or do not collapse into black holes, are stable enough. This means that these stars are able to maintain their existence over a long period of time.

In stars like our Sun, this feedback works in such a way that when the intensity of thermonuclear fusion increases, the core of the star expands. This expansion decreases the pressure and temperature in the core, which in turn reduces the rate of thermonuclear fusion. The star then contracts due to gravity, increasing the pressure and temperature in the core and thus the rate of thermonuclear fusion. Thanks to this regulation, the hydrogen needed for thermonuclear fusion lasts for billions of years in stars of this size. Over time, the process of SBS has led to the universe as we know it today, filled with a vast array of stable structures.

Examining Differences Between Selection and Stability-Based Sorting

The process of evolution is influenced by both selection and stability-based sorting, among other evolutionary processes that are beyond the scope of this article. Selection and sorting operate in distinct ways and have unique impacts on the course of evolution, leading to the emergence of different classes of properties.

Selection, in comparison to sorting, is a rapid process that can lead to the accumulation of beneficial traits in a relatively short time. This is largely due to the principle of inheritance, which allows useful innovations to be passed down genealogical lineages, enabling selected entities to accumulate these innovations. This process can lead to the development of complex adaptive structures through the step-by-step accumulation of beneficial novelties in a single genealogical lineage (Darwin, 1860). For instance, the cameratype eye of vertebrates or the human brain are highly complex and highly adaptive organs that have evolved in many steps through this process. Generally, most complex adaptive organs and behavioral patterns in living organisms originated by natural selection.

However, while selection is effective in the short term and can rapidly accumulate beneficial traits, it is stability-based sorting that determines which traits, species, and clades will persist in the long run. The first major advantage of SBS over selection is its ultimate authority in the evolutionary process. SBS is primarily concerned with stability, and entities that are not stable, regardless of their beneficial traits, will eventually be eliminated. The human brain, for instance, has allowed humans to dominate the Earth and potentially explore other parts of the universe. However, the same brain has also enabled the creation of destructive technologies, such as thermonuclear bombs, that could potentially wipe out a large part of the Earth's biosphere, including humans themselves. In contrast, SBS favors entities that lack such potentially autodestructive organs. For example, organisms like sloths or even tardigrades, which lack such complex and potentially dangerous organs as the human brain, may ultimately prevail on Earth and other planets due to their long-term stability.

The second major advantage of SBS is its seeming ability to "see ahead" or evolve traits that will be adaptive in terms of future sustainability. While selection is short-sighted and opportunistic, evolving traits that are useful in the current situation (Dawkins, 1996), SBS promotes traits that ensure long-term success. This can lead to the evolution of traits that may not be immediately beneficial but contribute to the long-term survival and stability of the entities (Toman & Flegr, 2017).

Consider, for instance, the ability of animals to slow down the rate of reproduction when resources are expected to be scarce. This trait might be advantageous for the long-term survival of the population or the species. However, the so-called "tragedy of the commons" principle impedes the evolution of such a trait through natural selection. If, for example, all birds in a flock begin to lay fewer eggs when the population density of their species is high and consequently there will likely be little food during the chick-feeding period, the population can avoid famine and, on average, raise more offspring than if its members tried to lay as many eggs as possible. However, if an individual appears in the population that continues to reproduce at the maximum possible rate even when the population is dense, it will raise more offspring than all the other individuals in the flock and pass on its mutation for selfish behavior to a larger number of offspring. The trait of reducing the intensity of reproduction in conditions of impending famine, therefore, cannot evolve and especially maintain in the population by the mechanism of selection.

In contrast, SBS can promote the fixation of traits that ensure the reduction or cessation of reproduction before resources are exhausted. This "safety mechanism," which might manifest as stress-induced reduced reproduction in overcrowded populations, is maladaptive from the viewpoint of individual selection. But it is crucial for the long-term stability of the population and therefore for the long-term success of the species. Thanks to SBS, most surviving species, the winners of the SBS contest, exhibit some form of safeguard against overpopulation.

To summarize, stability-based sorting is not confined to the demands of the immediate present and seemingly anticipates future development and the requirements of future environments. This foresight of SBS is in stark contrast to the opportunistic nature of evolution driven solely by selection. It is precisely due to this foresight that SBS plays a unique role in the evolutionary processes.

Application of Stability-Based Sorting Principle in Cultural Evolution and Other Fields

The stability-based sorting principle boasts broad applicability across diverse biological and non-biological fields dealing with evolving natural systems. Interestingly, this principle also provides insightful explanations for numerous phenomena spanning various domains of cultural evolution.

SBS can elucidate the ongoing process of solidification within both public and private institutions, such as state governance systems and public administration. This solidification often leads to these institutions becoming increasingly resistant to any form of change. The author's personal experience after the 1989 Velvet Revolution showed that it is possible to change almost everything immediately after a revolution that breaks down the current organization. However, the rate and scope of changes gradually slow down and eventually stop as unstable components of the system disappear and entities with various self-maintaining mechanisms accumulate over time through SBS. This facet of societal change has been highlighted from various viewpoints by numerous scholars. For instance, Kováč (2015, p. 26) stressed the progression of laws, ethics, culture, and political systems toward enhanced stability.

Like biological evolution, cultural evolution does not unidirectionally lead to absolute stability. It typically exhibits a punctuated character, alternating between relatively long periods of stasis and short periods of rapid, sometimes dramatic, changes (Eldredge, 1971; Eldredge & Gould, 1972).

In biological evolution, the transition from a frozen to a plastic state, which allows for dramatic evolution, is often caused by peripatric speciation (Flegr, 1998). This involves the separation of a small, non-representative sample of the population and its long-term independent progression, evolution isolated from the original parent population. Due to the initial non-representative nature of this small population sample in terms of allele representation, and the subsequent changes in this representation not caused by selection but by drift (randomness), many gene pool-stabilizing mechanisms that have accumulated over the long existence of the original species due to SBS can easily disappear (Flegr, 2010, 2013). This is especially relevant for sexually reproducing species, where heterozygote advantage and frequency-dependent selection (balancing selection) maintain polymorphism in numerous alleles. In small populations, all forms of selection, including frequency-dependent selection, are superseded by genetic drift or, in other words, by the workings of chance.

In the realm of cultural evolution, the triggers for such a transition are not yet fully understood. However, it is clear that natural or societal disasters, which result in the breakdown of existing social structures and institutions, can certainly catalyze this shift toward plasticity.

SBS can be applied to explain not only the evolution of society as a whole but also the evolution in various subdomains of cultural evolution. It can elucidate numerous regularities related to large memetic complexes, such as the spread of different religions. It is evident that religious systems with built-in internal stabilizing mechanisms, such as reliance on internal canonized texts, have a higher chance of long-term survival, and hence, we are more likely to encounter them in the contemporary world than religions that lack such mechanisms (Flegr, 2017).

In the field of political science, SBS can explain why elections in established communities often end in a political stalemate, with the two main parties or natural coalitions garnering a very similar number of votes. Such a state is evidently the most stable as it does not lead to any significant post-election changes in societal functioning. The internal cause of its stabilization may be analogous to frequency-dependent selection. In most societies, there is a considerable group of people who tend to automatically side with the opposition, regardless of which party is currently in power. Similarly, there likely exists a group of people who tend to join the weaker side; these two groups may not overlap at all, and their relative sizes may vary in different countries. However, their influence on the stabilization of the political space is very similar.

There are also other internal mechanisms that can ensure an electoral stalemate, but the final word in a global view is held by stability-based sorting. States in which an electoral stalemate is maintained by any internal mechanism over a long period are more stable. At any given time, we are more likely to observe states in these long-term stable conditions rather than those in brief, transitional phases. Therefore, the perceived prevalence of such stable states increases over time.

The phenomenon of sorting in terms of stability can significantly impact the competition between the democratic and non-democratic world. So far, the development shows that democratic systems better utilize the creative potential of their citizens, leading to greater economic prosperity. The appeal of democratic systems to the populations of other countries, along with their economic and subsequent military potential, exceeds the appeal and potential of non-democratic systems. As a result, at least in the last century, the representation of democratic states on Earth has gradually increased. However, this generally favorable development could be dramatically affected by sorting in terms of stability in the future. Due to technological advancements, the possibilities for repressive non-democratic systems to maintain their power, even against possible resistance from the population, or even to directly eliminate this resistance through targeted, professionally and effectively conducted propaganda, are constantly increasing. Therefore, it is possible that over time, the necessary technology and knowledge will reach a stage where it will not be possible to overthrow a dictatorial regime from within, meaning by the citizens' own efforts. In this situation, non-democratic systems could gradually accumulate, as the transition from a democratic system to a non-democratic one will still exist, while the transition from a non-democratic to a democratic one may not be possible.

Conclusion

The principle of stability-based sorting (SBS) is a fundamental mechanism that influences the evolution of entities across a wide range of contexts, from biology to culture, and even the evolution of the universe. Unlike selection, which operates on the principle of differential survival and reproduction, SBS favors entities that are stable and endure over time.

In the realm of natural sciences, SBS plays a pivotal role in, e.g., macroevolution, influencing the long-term success and persistence of species. It offers a unique perspective on the evolution of ecosystems, the dominance of sexually reproducing species, and the evolution of the universe itself. The recognition and comprehension of SBS's seeming ability to "see ahead" and evolve traits that ensure long-term success rather than immediate benefit provide a crucial perspective in our understanding of how various natural entities evolve over time.

The application of the SBS principle extends beyond the natural world to various fields such as cultural evolution and political science. It can elucidate numerous phenomena, such as the solidification of institutions, the political stalemate in established communities, and the competition between democratic and non-democratic systems.

Despite its significant potential, the principle of SBS has been unjustly overlooked in many areas of study. Recognizing and applying this principle can offer important and often surprising insights into the functioning of both the organic and inorganic world, as well as society. In conclusion, the principle of stability-based sorting offers a powerful lens through which to view and understand the evolution of various systems, and its unique ability to favor stability and long-term success over immediate benefit underscores its crucial role in our understanding of the world.

Cross-References

- ▶ Evolution by Non-individual Selection Pressures
- ▶ Macro and Microevolution
- ▶ Selection

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