A physics perspective on trial and error evolution and intelligence

Author: Eran Magshim Lavi

Affiliation: Independent researcher (Givatayim, Israel)

OrchID – 0000-0001-9063-1655

Email: eranlavi@eranlavi.com

Abstract

This article investigates the pivotal role of Energy in trial-and-error evolution (TAEE). I commence by discussing the Uncertainty principle, which introduces fundamental randomness to physical phenomena and imparts random variability to the TAEE (trial and error evolution). As Energy is the sole component of our Cosmos, the TAEE reflects in Energy and its changes: its exertion capabilities, storage, and ad hoc planning (of Energy exertion.) I then investigated TAEE as reflected in the emergence of intelligence. The Least action principle controls Energy movement in space-time; thus, intelligence emergence directly connects to structures' ability to use the Least action principle. For example, first-level nonintelligent structures (e.g., elementary particles, simple replicating molecules) cannot plan a path, and the Least action principle completely predetermines their infinitesimal movements. They cannot control their Energy exertion, store Energy, or plan ad hoc. After a long process of TAEE, intelligent structures emerged with advanced Energy control, robust Energy storage, and ad hoc planning, allowing complete ad hoc path planning and the ability to make unrestricted mid-course path adjustments. This progression underscores the intricate relationship between Energy dynamics, trial and error evolution, and intelligence evolution.

Article

1. Introduction

In this article, I provide a physics-based foundation for understanding trial and error evolution, which ultimately culminates in the emergence of intelligent structures. While intelligence is often defined within fields like psychology, cultural studies, and cognitive science, these definitions typically overlook the role of fundamental physics. Here, I explore the physics driving the evolutionary process and trace the principles that facilitate the emergence of intelligence.

In physics, Energy is everything: Energy represents both the substance of the Cosmos and the ability to cause changes in the Cosmos.

In the form of a principle:

The Completeness Principle:
Energy and nothing but Energy exists in the Cosmos.

Therefore, all processes and their influences in space-time are Energy and its changes. Thus, Energy and its applications in space-time must be the basis for trial and error evolution analysis.

Energy always conforms to the "Uniformity of Physics Laws in the Universe Principle:" **Each physics law is the same throughout the Cosmos**. Energy always obeys the **"**Energy Conservation Principle:" **Energy in a closed system is conserved and finite**.
Nobody has ever found a deviation from these principles on Earth, the solar system, or in distant galaxies. (1)

2. Uncertainty, and trial and error evolution

All processes in space-time follow the Uncertainty Principle: "**Each process in space-time has ingrained Uncertainty**." Practically, we cannot foresee precisely all quantities of processes in space-time. (This is not a reflection of our inability to observe all possible quantities to the utmost accuracy but a reflection that there is true uncertainty in all processes in space-time.)

The ingrained uncertainty results from uncertainty-related Energy. **Uncertainty-related Energy is Energy that randomly appears and disappears in space-time without an observable source**. This Energy appears everywhere, and due to its unpredictability, it introduces uncertainty to all processes in space-time.

Uncertainty-related Energy is the source of trial and error evolution processes:

Trial and Error Evolution Processes Definition:
Trial and error evolution processes are processes in space-time that create structures.

Structures Definition:
Structures are distinct entities emerging from binding one or more elementary particles to one or more elementary particles, which remain for a period.

In trial and error evolution processes, many universe parts combine and disintegrate randomly, creating structures in the process. The source for these universe parts combinations and disintegration is the uncertainty-related Energy that randomly appears and disappears everywhere in space-time, causing random Energy movement and changes. **Note**: Uncertainty-related Energy changes are noticed mainly in molecular and sub-molecular structures.

It takes many trials to form structures because structures are constantly assailed by Energy, which can cause their disintegration. Once a structure emerges, it preserves its existence unless some processes propelled by the uncertainty-related Energy cause changes in it. From time to time, the uncertainty-related Energy changes structures. If a change in a structure contributes to its existence, it will continue to exist longer than without the change. More significant are the changes to the structures' hereditary systems (if they exist). If these changes contribute to the descendants' existence, the number of species members will increase over time. Correspondingly, if the change is bad for existence, the structure's existence may suffer - even up to the cessation of its existence. If these changes harm the descendants' existence, the number of species members will decrease over time.

Note: This description is a simplistic view of a complex process but represents its most basic and essential qualities and origin.

Going forward, I will abbreviate trial and error evolution processes to "**TAEE**."

Aside: Highly evolved intelligent structures can change hereditary components or create new biological or mechanical species - including AGI, by design rather than by "natural" random changes. As the creators of these actions result from previous TAEE (trial and error evolution) processes, the artificial manipulation of hereditary components and the creation of new species still fall under TAEE as part of the chain of TAEE.

To better understand TAEE, I followed the TAEE path on our planet, which led to intelligence creation. This approach does not limit TAEE understanding to TAEE on Earth alone because all TAEE in the Universe will follow the same physics principles with varying degrees of adaptation to the TAEE's actual process environment.

3. Nonintelligent structures evolution

First-Level Nonintelligent Structures Definition:
First-level nonintelligent structures are elementary particles and structures that immediately exert Energy received from external sources, cannot store Energy, and cannot plan.

In this article, I will start discussing TAEE after the creation of elementary particles. (I will discuss elementary particles creation in another article, which shows that their creation also results from TAEE.)

The TAEE first created elementary particles. Then, TAEE created "**Non-Replicating Structures**":

- Elementary particles created composite particles (in TAEE.)

- After creating enough composite particles, the composite particles created protons, neutrons, and electrons (in TAEE.)
- After creating enough protons, neutrons, and electrons, they created atoms (in TAEE.)
- After creating enough atoms, they created molecules (in TAEE.)

Note: The creation of atoms constitutes the beginning of "**Chemistry**."

The structures described above have no control of Energy exertion, no Energy storage, and no (ad-hoc) planning. Therefore, they are all first-level nonintelligent structures.

From close to the end of Earth's oceans' creation, lasting 200-300 million years, a giant step in TAEE emerged: non-replicating structures, such as molecules, underwent evolutionary transformations that enabled them to start replicating themselves. This process led to the formation of "**Simple Replicating Structures**" (which are also first-level nonintelligent structures). Scientists suggest it occurred near hydrothermal vents in the ocean. To gauge the intensity of TAEE interactions, I calculated that in the time frame mentioned above, near a single hydrothermal vent (within 40 cubic meters around it), there would be $8.45 \cdot 10^{58}$ interactions between seawater molecules, minerals, and other non-replicating structures close to the hydrothermal vent. There are currently more than 500 hydrothermal fields in the oceans, each consisting of hydrothermal vents. Their areas range from a few square meters to several square kilometers. There were many more hydrothermal fields right after the ocean's creation; since then, the Earth's crust has been more active than it is today. For 1,000 hydrothermal fields with an average of 100 hydrothermal vents, the number of interactions increases to $8.45 \cdot 10^{63}$ within the mentioned period - a staggering number representing the TAEE's very high trial numbers. (2) (Appendix A)

In general, the jump from non-replicating structures to simple replication structures requires the concentration of enough non-replicating structures, Energy for the TAEE, and enough time for TAEE to perform its function. **Remark**: This process can occur almost everywhere in the Universe - if the conditions mentioned above exist.

Processes in space-time always obey the "Energy Conservation Principle." From observations, we know that processes tend to be in states with the lowest possible potential Energy states, which leads to the following:
Macroscopically, in systems where the Hamiltonian is time-independent, processes follow the "Least Action Principle": **A Universe part path has minimal Action for stationary start and endpoints**. This principle inherently embodies the "Energy Conservation Principle"—since in systems with a time-independent Hamiltonian, the total Energy remains finite and constant over time. (3)

Mathematically, if a Universe part has an action $S = \int \mathcal{L} d^4x$, where $\mathcal{L}$ is the Lagrangian density, then the "Least Action Principle" translates to $\delta S = 0$ with fixed start and endpoints, which produces the Universe part path. (Remark: In classical mechanics, we use the Lagrangian "L" in 3D instead of the Lagrange density in 4D.)

Without change in the Hamiltonian with respect to time, space-time movement always follows infinitesimal progress increments according to the "Least Action Principle." This situation represents a lack of internal control over Energy exertion. (Atoms do not decide when to exert their charges' Energy – they always do.)

All first-level nonintelligent structures (elementary particles, non-replicating structures, and simple replicating structures) follow the “Least Action Principle” without any control over its endpoints, which means that they progress following the “Least Action Principle” without a plan for a path (they do not have a target for their movement.) **Note**: This does not mean that random uncertainty-related Energy does not influence their path occasionally.

After nearly half a billion years of continuous TAEE, TAEE created second-level nonintelligent structures.

Second-Level Nonintelligent Structures Definition:
Second-level nonintelligent structures are structures that can control Energy exertion in a limited fashion. They can store Energy. They cannot plan ad hoc.

The following evolutionary steps relate to second-level nonintelligent structures (Note: dates of evolutionary results’ appearances vary significantly between different scientists. The dates are less important than the results. I only mention the results and not the less important (for the article) intermediary evolutionary stages):

Since the appearance of simple replicating structures, hundreds of millions of years of TAEE passed until about 3.5-3.8 billion years ago, when a giant step in TAEE emerged: the first cells - **Prokaryotes** - cells without a nucleus appeared. These structures developed a closed internal environment adapted to support their survival, reducing their reliance on external environmental conditions alone. They could control Energy exertion in a limited fashion and store Energy but could not plan ad hoc. (4)

Note: Simple replicating structures that led to the creation of the first cells constitute the beginning of “**Biology**.”

From early in their evolution, prokaryotes developed the ability to respond to environmental changes through simple mechanisms like chemotaxis, thermotaxis, and phototaxis. These reactions are the first form of reflexes in organisms. That means they have some control over Energy exertion, but they do not plan ad hoc - their reactions are preprogrammed and part of their genetics. (5)

1.6-2.1 billion years ago, a more advanced cell type appeared – **Eukaryotes** - cells with a nucleus and organelles, which significantly improved the cell's existence ability and its reproduction. All eukaryotes have reaction types similar to those of prokaryotes. (6)

It took another ~200-900 million years for another major advancement in TAEE: the appearance of the first multicellular structures from eukaryotes. Some of these multicellular structures developed instincts (and I named these structures “**Instinctual Multicellular Structures**”) while others did not (correspondingly “**Noninstinctual Multicellular Structures**”). Instinct Definition: **An instinct is a fixed complex pattern of behavior in response to certain stimuli. It is inborn and occurs without prior experience or training**. Scientists believe that instincts developed from reflexes, combining them into a more complex set of instructions and choices of actions. (7)
Remark: in this article, whenever I refer to instinctual multicellular structures, I refer to those with instincts and reflexes that do not plan ad hoc.
Aside: Some multicellular structures are composed of prokaryotes, but they are simple and

not worth mentioning in a separate description in the context of this article. They fit all that I attribute to second-level nonintelligent structures.

Discussion: Prokaryotes, eukaryotes, and both instinctual and non-instinctual multicellular structures exhibit some degree of control over their Energy exertion, responding to changes in their neighborhood. However, their actions are not based on ad hoc planning but are genetically predetermined. Since these responses are preprogrammed rather than tailored to specific situations, their Energy exertion is suboptimal. Their Hamiltonian function depends on time, meaning they can modify the "Least Action Principle" endpoints but only within certain constraints. This capacity allows them to adjust their endpoints based on their neighborhood perception - when a new or changed stimulus triggers their preprogrammed response. Initially, the organism follows one endpoint for the entire planned path. However, if the existing stimulus changes or a new one appears mid-response, the organism may set a new endpoint for the remaining path to adapt to the new conditions.

An extraordinary thing happened:

Equation 1 TAEE bypasses the single setting of an endpoint of the "Least Action Principle."

$$f_{TAEE}\big(E(q,\dot{q})\big) = E(q,\dot{q},t) \rightarrow in\ 3D\colon\ if\ E = H\ then\ f_{TAEE}(E) = H + \frac{\partial L}{\partial t}$$

Where f_{TAEE} represents the long process of TAEE transforming first-level nonintelligent structures into second-level nonintelligent structures. f_{TAEE} created structures that can control their movement by bestowing them with the ability to change the endpoints determined by the “Least Action Principle” during their movement.

4. Intelligent structures evolution

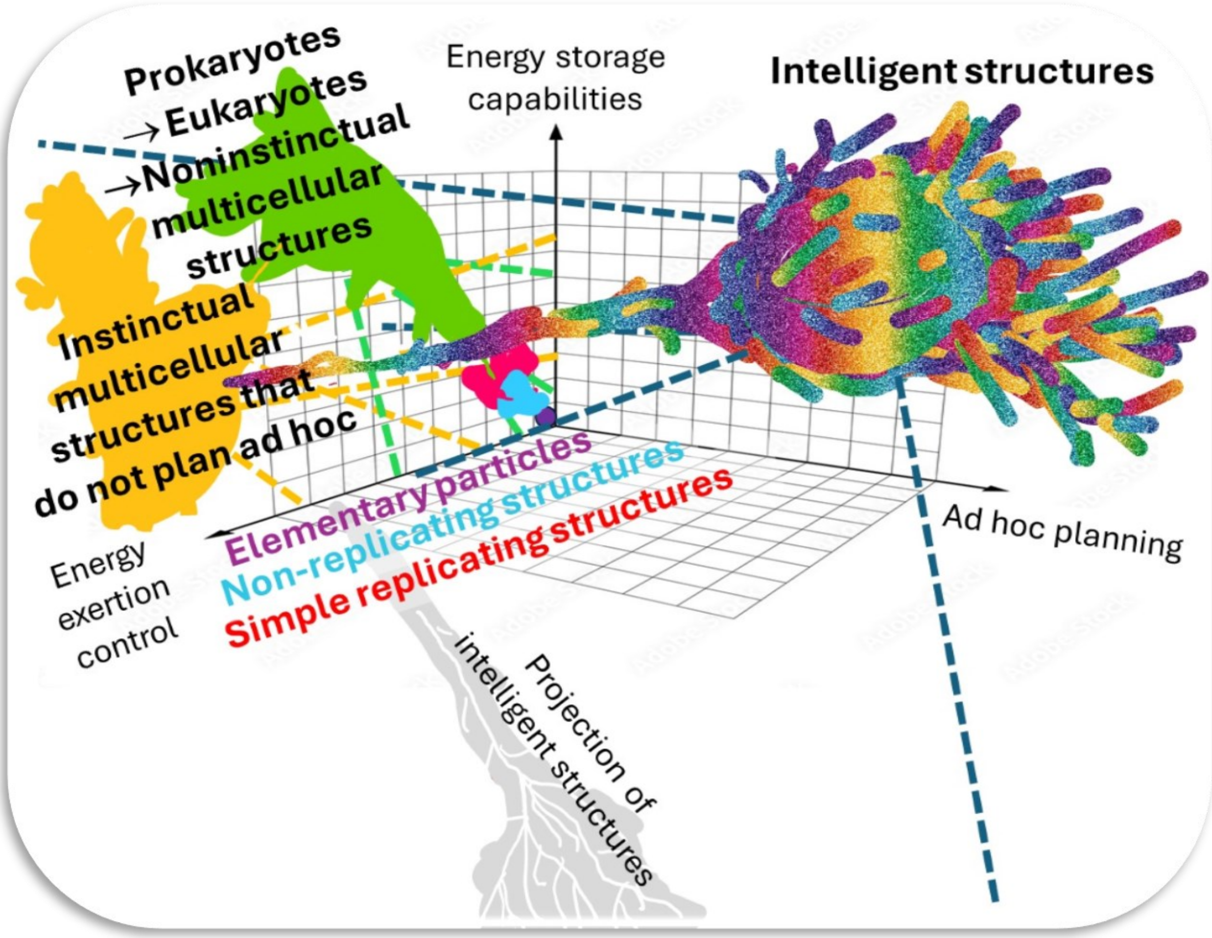
The success of instinctual structures (that do not plan ad hoc) "led" TAEE to "exploit" their ability to change the endpoints appearing in the "Least Action Principle" in mid-path. The TAEE process created structures that can plan ahead a multisegmented path before following it, coupled with the ability to change the multisegmented path endpoints (of the "Least Action Principle") even in mid-paths as many times as the structure "desires." This change requires more control over Energy exertion, more Energy storage capabilities, and ad hoc planning.

Simplistic example: When we walk and notice a big rock ahead, we plan a path to bypass it. This path may contain many sub-paths. At each step, we can look at the ground beneath us and may change our step to accommodate a better lending place for our foot corresponding to the ground state we step on, resulting in many changes of start and endpoints at mid-paths.

Intelligent Structures Definition:
Intelligent structures are structures that can control their Energy exertion, store Energy, and plan ad hoc.

The intelligent structure comprises several substructures specializing in input gathering, Energy storage, controlled Energy exertion, and ad hoc planning. These substructures can be very complex. As an example of the complexity of a large system that stores, retrieves, and analyzes data, reaches ad-hoc decisions, and sends orders to the organism's different organs, there are grosso modo $1.36 \cdot 10^{26}$ atoms in a Homo Sapiens brain. (Appendix A)

Figure 1 Schematics of intelligence development through TAEE



In Figure 1, the components are not scaled in size, exact relative position on axes, and time of appearance.

All the nonintelligent structures reside in the Energy exertion control and the Energy storage capabilities plane: Elementary particles appear as a purple circle (should be a dot) at the origin of the axes. The non-replicating structures in light blue (containing composite particles, atoms, and non-replicating molecules) emanate from the elementary particles. The simple replicating structures in red emanate from the non-replicating structures. A group of three: the prokaryotes - emanating from the simple replicating structures; the eukaryotes - emanating from the prokaryotes, and the noninstinctual multicellular structures - emerging from the eukaryotes - all three are in a shade of green (I combined these three types into one to avoid visual clutter.) The instinctual multicellular structures that do not plan ad hoc in a shade of yellow emerge from the eukaryotes/ noninstinctual multicellular structures. All of the nonintelligent structures have changing surfaces and appendages to demonstrate TAEE.

The intelligent structures in multicolor - emanate from instinctual multicellular structures that do not plan ad hoc. They are all over the three axes (including the ad hoc planning axis) with multiple appendages demonstrating their flourishing TAEE many turns.

Alternative intelligent structure definition:

An Intelligent Structure Definition:
An intelligent structure is a structure that tries to foresee the future. It exerts Energy in a controlled manner according to its forecasts to achieve its goals. It plans ad hoc, including dividing its actions into many connected sub-actions. While executing the actions, it can change them (by changing the points appearing in the "Least Action Principle") even when the structure is in any of the mid-planned sub-actions, as many times as it wishes.

Aside: Life on Earth shows signs of intelligence much sooner than some scientists believe.

Note: The "Uniformity of Physics Laws in the Universe Principle" ensures that intelligence develops everywhere in the Cosmos - because all processes in space-time follow the same principles discussed here. Because conditions differ in many parts of the Cosmos, intelligent structures in different parts of the Universe may vary significantly.

5. Conclusions

The uncertainty-related Energy that appears within elementary particles and their neighborhood propels the TAEE.

TAEE created processes that allow for the division of actions into many sub-actions and the ability to change the points appearing in the "Least Action Principle" (which guides action progression) - even in all mid-actions. TAEE did that from processes that do not allow changing the points in the "Least Action Principle."

Intelligent structures' ad hoc planning allows for actions that are accumulatingly **better** for continued future existence over current considerations alone. This quality makes them the best structure type TAEE created for prolonged existence because they can potentially prepare for more existential threats than any other structure type.

As the best existential strategy (yet,) intelligence will appear anywhere it can in the Universe in many (possibly) different forms.

6. References

1. *Testing feedback-modified dark matter haloes with galaxy rotation curves: estimation of halo parameters and consistency with CDM scaling relations.* **Katz, Harley.** s.l. : Monthly notices of the Royal astronomical society, 2017, Vol. 466.

2. **Charles Q. Choi.** Astrobiology at NASA. *Life in the Universe.* [Online] https://astrobiology.nasa.gov/news/lifes-building-blocks-form-in-replicated-deep-sea-vents/.

3. *A methodology for formulating dynamical equations in analytical mechanics based on the principle of energy conservation.* **Wang, Yinqiu Zhou and Xiuming.** 035006, s.l. : Journal of Physics Communications, 2020, Vol. 6.

4. *Comparative genomics and the evolution of prokaryotes.* **Abby, S.** 3, s.l. : Trends in microbiology, 2007, Vol. 15.

5. **Battistuzzi, Fabia U.** *A Major Clade of Prokaryotes with Ancient Adaptations to Life on Land.* s.l. : Department of Biology, Pennsylvania State University.

6. *The Syntrophy hypothesis for the origin of eukaryotes revisited.* **López-García, Purificación.** s.l. : Nature Microbiology.

7. *Bangiomorpha pubescens n. gen., n. sp.: implications for the evolution of sex, multicellularity, and the Mesoproterozoic/Neoproterozoic radiation of eukaryotes.* **Butterfield, Nicholas J.** 3, s.l. : Paleobiology, 2000, Vol. 26.