

Cosmology of Information

1. Resonant Universe and Communication

For instance, even fish swimming in the ocean use sound waves and ultrasonic waves to connect with each other through the vibrations of seawater, influencing each other mutually. Moreover, the act of swimming by the fish itself creates vibrations in this medium, which in turn affect other fish. Just like this, could it be that every element of the universe perceives and recognizes each other? Furthermore, through this mutual recognition, could it be that both the material and living worlds emerge new structures and organizations? Similar to our society, the universe itself might be a creative society constantly forming new forms through the exchange of information, operating as a self-organizing system.

In fact, according to string theory, this universe is said to be composed of vibrations of resonating strings, much like the resonance of strings on a violin. As many strings resonate together, events in the universe resonate with each other. The universe is, in a sense, a music played by countless harmonies. Galaxies, stars, the sun, the moon, Earth, matter, life, and everything else emerging in this universe resonate with each other with various rhythms and exchange them.

In the microcosmic world, elementary particles resonate and vibrate non-locally with each other. When these particles synchronize, they aggregate in specific directions and create distinct patterns. They exchange information and mutually recognize each other. Atoms resonate at specific frequencies and bond with each other while molecular vibrations lead to resonance and crystallization. Whether in electrical or mechanical vibrations, synchronization occurs autonomously through mutual excitation, even if frequencies are slightly different. In the material world, as in society, elements continually recognize each other, cooperate, and form various patterns.

In the realm of living organisms, elements also resonate with each other. Within a single organism, molecules, cells, and organs resonate, momentarily creating the coherence of a living entity. This conjugate relationship persists even when elements

are physically separated, with waves of resonance constantly traversing within living organisms. Heart cells beat in synchrony, muscles cooperate to enable consistent movement patterns, creating rhythms among elements. This rhythm not only harmonizes the elements but signifies the essence of life itself. Moreover, our bodies resonate with the rhythms of the Earth's rotation and revolution, and even with the lunar cycle.

Slime molds, transitioning from amoeboid forms, suddenly exhibit coordinated behavior to form collective entities. Fish in the sea and birds in the sky also engage in coordinated behavior. Within and beyond their bodies, living organisms continually recognize each other, exchange information, and create harmony.

In a state where all phenomena in the universe resonate with each other, a simple cause-and-effect diagram does not hold true. Here, each element serves as both cause and effect; causes become effects and effects become causes. Causes and effects cycle, and causality collapses. Phenomena like resonance cannot be captured by linear cause-and-effect thinking.

In a world where countless elements resonate together, one could say communication is occurring between these elements. Communication is a simultaneous co-occurrence and synchronization phenomenon. When this synchronization occurs, information is transmitted and recognition takes place. Communication isn't merely the transfer of energy or matter from one system to another; it's the co-occurrence of systems.

In this sense, from elementary particles to molecules in the material world, elements resonate with each other, communicating and interacting. Especially in the more highly organized world of living organisms, no system can exist without communication. Even single-celled organisms communicate using chemical signals. In multicellular organisms, comprised of many cells, communication between cells is essential for unified regulation. Each cell recognizes each other, creating a unified system.

Furthermore, as organisms become more advanced, communication systems such as immune systems using molecular recognition, endocrine systems regulated by hormones, and nervous systems transmitting electrical signals become more

sophisticated, enabling coordination of biological functions and adaptation to the environment.

Things born into the universe are not isolated; they are interconnected. From elementary particles to galaxies, all entities, no matter how distant, are dynamically interconnected. Within these mutual interconnections and couplings of entities lies the issue of information and recognition.

In such a world of mutual interconnectivity where all elements interact with each other, each element resonates with others. Here, the vibration of one element stimulates the vibration of another, creating a chain of resonance. Moreover, within this inter-element resonance, information is born as transmitters and receivers synchronize. Receiving information through resonance is nothing but recognition. We must acknowledge that elements of the universe resonate with each other, exchange information, and mutually recognize each other.

2. Matter, Energy, Information

Information creates the structure and order of matter, bringing about self-organization in the universe. When information is provided, entropy decreases and organization increases. The reduction in entropy and increase in order occur through the differentiation between A and non-A, and it is precisely at this point of differentiation that information operates. This universe has self-organized into more complex entities, but for this self-organization to occur, interactions are necessary. Moreover, for these interactions, information is required, not just matter and energy.

Just as a ship avoids reefs and forms safe routes through signals, matter also forms its own patterns through information. Information binds together many elements, giving them form. Information is essential for processes such as plasma formation and crystal generation. Moreover, receiving this information is nothing but perception. Information transfer plays a significant role in the emergence of new structures in nature.

Describing this universe requires not only the concepts of matter and energy but also the concept of information. Information, along with matter and energy, is a crucial aspect of the universe. In fact, in today's physics, matter is described as waves in the sea of energy, with this energy transforming into information, which then creates work. For instance, when an electron collides with a positron, their energy converts into light, and by absorbing this light energy, electrons within atoms move to outer orbits. This movement signifies that atoms have acquired structural information. The absorbed energy of light has brought about an increase in information within the atom, resulting in the creation of more complex structures. Light, being a form of electromagnetic wave, serves not only as a form of energy but also as a medium of information, triggering the self-organization of matter.

Living organisms such as plants and animals are sophisticated systems that convert matter into energy and transform energy into information. For instance, in photosynthesis, plants utilize the energy of light as information to combine carbon and hydrogen, thereby creating more advanced structures and organizations. Matter converts to energy, energy converts to information, and information converts into the structure of matter. Moreover, these processes can occur in reverse. Nature can be described as the mutual conversion of matter, energy, and information.

Modern natural sciences initially aimed to describe the world using as few basic concepts as possible and initially focused on matter. However, it became apparent that matter alone was insufficient, leading to the introduction of the concept of energy. Yet even with these two concepts—matter and energy—the world could not be fully described, necessitating the introduction of information concepts, which characterizes the current state of modern natural science. To describe the self-organization of galaxies, stars, planets, atoms, molecules, cells, and organisms, it is essential to consider not only matter and energy but also information and its reception—factors such as perception and observation. This is where the necessity of an information-based cosmology lies.

According to Shannon, information involves selecting one state from several possible states. When a selection is made, differences arise within the system, and these differences constitute information. Information is the encoding of differences. Moreover, differences lead to a decrease in entropy. When a choice is made and differences arise, information is generated, reducing the disorder of the system. In other words, entropy decreases and order increases. Furthermore, the information

thus generated is transmitted to other systems, giving rise to choices in those systems. This, in turn, creates further differences and generates order. Thus, through the cycle of selection, differences, information, and order exchange—essentially through communication—the universe comes into being.

Galaxies, stars, particles, atoms, molecules, organisms—all serve as both transmitters and receivers of information. The various elements of the universe self-realize through information. Furthermore, as organizational complexity increases from the material world to the realm of life, information itself evolves from signals to symbols. For example, when a dog hears the sound of a bell, on a material level, the sound waves from the bell resonate in the dog's eardrums, serving some role as a signal. Yet on a life level, the dog perceives the sound of the bell as a symbolic representation of food, resulting in salivation. As organizational complexity increases, interpretations of meaning and value from the perspective of the receiver are inherently embedded in information.

Existence is relational. Information constitutes a part of this relationship. Through the transmission of information, relationships between substances are maintained, and communities of organisms emerge. Interaction exists where there is relationship, and things come into being where there is interaction. Information enables these interactions, and recognition of this information constitutes consciousness. Without recognition, there is no existence.

3. Self-organization and Information

Life, as well as matter, is not passive as conceived in a mechanistic worldview. Matter spontaneously self-organizes. Crucially, this self-organization requires information. Information edits the behavior of matter, organically structuring it. For work to be done, there must be a supply of information. When information is supplied to a system and the conditions of matter and energy are sufficient, the system organizes further, generating new structures. In self-organizing systems, there is a phenomenon of phase transition where at certain stages, a leap to a completely different level can occur, which should also be examined from the perspective of

information. From matter to life, the organization by information has formed increasingly complex structures.

New orders are produced not only by matter and energy but also by inputting information. Information provides order and shapes form. Moreover, the generated order itself contains information and has the ability to emit and transmit information. Information shapes new patterns. By introducing the concept of information, even within modern science, classical notions of formative and teleological causes can be revived.

In systems evolving through self-organization, whether in the cosmos, matter, or life, when approaching a branching point, it is not always determined which direction to take. Here, information plays a crucial role in selecting a state, breaking symmetry. This leads to highly organized directions within the system, generating new orders. Organization by information is determined by choices. Thus, chance plays a significant role here, and the laws of causality do not always hold. While causality suggests everything is determined by initial conditions, organization by information introduces non-deterministic ambiguity. Indeed, the newly generated orders are not predictable from the outset, highlighting the emergent nature of self-organizing systems. Information inherently resides in a creative universe.

New orders cannot be created without information. Information functions to combine simpler units into more complex systems. Thus, when this function is applied, relationships are altered, and new orders are generated. Furthermore, when new orders are formed, new information is also born. Information creates information. In self-organizing systems, even if initial conditions are set, the subsequent results are not definitively deterministic. This is because such systems autonomously generate information dynamically. Thus, this universe continuously generates new structures and forms, hierarchically. The role of information and its perception is significant in the structure of this self-transcendent universe.

4. Information and Entropy

Entropy, according to the second law of thermodynamics, is supposed to always increase. However, in self-organizing systems, entropy decreases instead. Yet, for self-organization to occur, information is necessary. By introducing information into a group and making selections, the original disorder diminishes accordingly. In other words, entropy decreases. Adding information reduces entropy and enhances organization.

Alternatively, receiving information can be seen as acquiring negative entropy. Acquiring negative entropy leads to gaining organization. As entropy decreases, the amount of information increases, contributing to establishing order. Conversely, without information, even with matter and energy, there would be no organization or order. The concept of information imbues order and structure, providing an exploration from the disorder represented by entropy.

For instance, as Schrödinger discussed in "What is Life?" (Chapter VI), life sustains itself by ingesting information, consuming negative entropy, and maintaining a low entropy state. Life builds from molecules to cells, tissues, organs, and organisms, continuing to evolve. This process involves consuming negative entropy to increase order, necessitating the acquisition of information. Life is a self-organizing system that acquires information, decreases its own entropy, discards excess entropy to the environment, and evolves, thus representing a complex system.

Life exists as both material and energy systems, but it is also an informational system. Beyond energy alone, life requires information to organize matter. Understanding life's essence requires consideration of relationships between parts and with the environment, which are governed by information. Information creates order in relationships. As organisms evolve, systems such as genetic, endocrine, immune, and nervous systems were developed to establish order through information transmission. Acquiring new information has enabled the evolution of life. Therefore, acquiring information, namely cognition, is indispensable for maintaining and evolving life—it belongs to the essence of life phenomena.

Of course, the reduction of entropy, or the formation of order, is not exclusive to life. In the material world, in thermodynamically non-equilibrium systems, order is formed by following paths that minimize entropy production. Even in these cases, information is essential for creating order. Self-organizing systems acquire information, reduce internal entropy, and create order. Processes such as the

formation of atoms, molecules, convection, and crystallization illustrate how simple systems become more complex. Thus, receiving information, or the role of cognition, plays a crucial role.

Conversely, in both material and biological systems, when entropy increases—such as in the dissolution of crystals, evaporation of liquids, or the death of living organisms—information decreases, and organizational structure is lost. When information is lost, entropy increases, and organizational structure disappears. In extreme cases, if information were reduced to zero, entropy would become infinite, and organizational structure would vanish. The structure of organization is formed by connections between elements, and information creates those connections.

As long as the universe continues to expand, overall entropy will inevitably increase, leading eventually to heat death, as described by the second law of thermodynamics. However, throughout this process, locally, entropy decreases continuously. Matter self-organizes and gives rise to life. In this cosmic process of forming order and evolution, the roles played by information and cognition are significant.

5. Life and Information

Life is an entropy-decreasing system that supports the formation of order and evolution in the universe. Therefore, in order to form this order, life has adopted the strategy of organizing through information. As evidenced by genetic strategies, immune mechanisms, and memory functions, the complex organization of matter and energy that we call “life” cannot exist without the accumulation, storage, and transmission of information. Whether it’s the genetic code or neural impulses, the transformation, symbolization, and compression of information are necessary for organizational purposes. For life to organize physical systems more effectively, more advanced information processing mechanisms were necessary.

Life cannot be generated solely by physical forces or chemical materials; it requires the addition of information. To understand life, we must consider not only kinetic and material factors but also teleological and morphogenic factors, wherein information

plays a crucial role. Systems governed by information are determined through selection. Even a simple organism like a tardigrade must choose whether to approach food or evade obstacles. Cognitive ability interprets the meaning of objects and enables decision-making. From these choices, purposes and forms emerge.

Life acquires, recognizes, preserves, exchanges, converts, and metabolizes information to create order. The ability to interpret the meaning and value of information, namely cognitive ability, is essential for the maintenance and evolution of life. As cognitive ability improves, so does the complexity of life's evolutionary information processing capabilities.

A characteristic of information for life is its recursiveness. When life forms acquire information from the external environment, they react to it. These reactions themselves become information that cycles back into the organism, governing both the maintenance of homeostasis and evolution. By acquiring information, life selects order, feeds back these choices to itself, and continues to select subsequent orders. Within this cyclical flow of information, the individuality of living organisms emerges. Just as animals adjust their breathing rate in oxygen-poor environments or recover balance after disturbances, without the recursiveness and cycling of information, organisms would not have survived.

Living beings are dynamic open systems open to their environment. Information measures their relationship with the environment in which they exist. Therefore, organisms metabolize information along with matter and energy. Organisms receive information from the environment, make choices and judgments based on it, and actively respond to the environment. Through this iterative process, organisms strive for active and spontaneous adaptation to environmental changes such as maintaining homeostasis and evolution. Active adaptation to the environment requires acceptance and recognition of information.

Living organisms possess various cognitive mechanisms, including genetic systems that enable cell reproduction and morphogenesis, endocrine systems that maintain homeostasis and facilitate growth, immune systems that recognize foreign substances from the external environment, and nervous systems that enable sensation and perception. These mechanisms exist to actively adapt to changing environments. Organisms continuously interrelate these information transmission systems to achieve self-preservation and self-transformation. Even bacteria, the

most primitive organisms, recognize specific sugars appearing before them through chemical reaction systems, create enzymes suitable for them, approach them, and ingest them. For organisms to sustain themselves, mechanisms for recognizing and transmitting information are essential.

Furthermore, life has even created information itself. Not only does life adapt to the environment, but it also reinterprets and creates new meanings from it. Through these new meanings, life reintegrates itself and evolves. Attention must also be given to the role of information creation in the evolution of life.

In genetic strategies of life's evolution, genes not only preserve and transmit information but also incorporate external environmental information, reassemble themselves, create new meanings, and enable evolution. Random genetic mutations and natural selection alone cannot achieve adaptive responses to environmental changes nor sufficient evolution. Conversely, environmental changes and their information are actively incorporated by genes, playing a crucial role in determining morphological variations. Genes constantly fluctuate, sensitively receiving information about environmental changes, and quickly reorganizing in a consistent direction. Genes do not predict environmental changes in advance but rather read changes in the environment on the spot, reassemble genes, reconstruct meanings, and reorganize in a consistent direction.

In this sense, genes must be acknowledged for their ability to interpret and reinterpret information and create new meanings. Autonomous evolution is made possible by the reorganization capability of genes. Indeed, genes serve as a kind of memory storage for storing environmental and morphological information. However, genes must be viewed not merely as devices for accumulating information but as devices for actively reorganizing information to adapt and evolve in the environment.

Life's evolution in this universe counters the second law of thermodynamics by increasing organization from simple systems to complex systems. In this sense, life is a self-transcendent system, and for this self-transcendence, information, its recognition, and further reorganization of information are indispensable.

6. Ecosystems and Recognition

The Earth's ecosystem is also a system of information and recognition. An ecosystem is an organic system where biological elements such as plants, animals, and microorganisms, as well as non-biological elements like water, air, soil, rocks, hydrogen, oxygen, carbon, and carbon dioxide, are closely interconnected and continuously fluctuate as a whole. Biological and non-biological elements interact through the exchange of matter and energy. From small puddles to forests, grasslands, rivers, lakes, oceans, and the entire Earth, the Earth's ecosystem, resembling nested structures, is a system where each component interacts through the circulation of matter and the flow of energy.

Furthermore, ecosystems are sensitive and responsive to external as well as internal fluctuations, constantly changing. Besides cyclical variations like daily, monthly, and seasonal cycles influenced by Earth's periodic changes, there are non-periodic transitions such as fluctuations related to solar sunspots, changes in Earth's magnetic field, climate variations, soil changes, shifts in nutrient supply, and movements of biological populations. Ecosystems are always in flux, never at rest, changing even with subtle fluctuations, making their prediction challenging. The sequence in which new species enter an ecosystem can alter its subsequent dynamics, contributing to each ecosystem's unique history and trajectory. Thus, the changes in ecosystems are fundamentally irreversible.

Ecosystems are inherently interconnected worlds where each element interacts horizontally and vertically in their relational space, influencing one another. Therefore, even slight fluctuations in internal and external elements of ecosystems propagate through their relational spaces, causing overall changes. Thus, ecosystems constantly evolve and generate change through the interconnections between their elements.

Moreover, in ecosystems, not only do substances circulate and energy flow, but information also circulates. Each element within an ecosystem is an open system that reads information from its environment—a recognition system. By receiving and recognizing information, each element creates order. Therefore, individuals cannot be viewed separately from their environment within ecosystems. They receive information from the environment, perceive it, make choices, and adapt to their environment. Thus, elements within ecosystems are significantly influenced by and

also influence their environment. It is within this interaction with the environment that the flow of information and recognition processes occur.

In other words, in ecosystems, fields are formed from interactions between elements, and each element changes its function, characteristics, and expressions based on its relationship with the field. Within the ecosystem's field, each element reads the environment in which it exists and changes while resonating with the field. In ecosystems, no single event can be isolated from others. The role of information and recognition is crucial in forming such fields. From bacteria to humans, organisms cannot survive without information. It is through information metabolism that organisms can adapt to their environment. Hence, there exists a role of recognition in life itself.

7. Information and the Universe

The material world is also a realm of self-organization through information and its recognition. Elementary particles interact with each other through their respective fields. These particles resonate and mutually excite with the vibrations of their fields. They exchange and recognize information with each other. Particles receive information from others, recognize it, and transition to new states. Thus, self-organization into atoms and molecules occurs. Furthermore, atoms and molecules communicate information, recognize each other, and organize accordingly. Genetic and immune systems, for instance, utilize molecular recognition.

Information is transmitted through fields, triggering movement in particles, atoms, and molecules upon reception. This movement propagates through a common field affecting all elements. Unlike classical physics, where objects are considered independently, every object is influenced by its surroundings and relationships. Being influenced implies sensitivity and recognition.

Matter and mind are dual aspects of reality and cannot be fundamentally separated. As matter evolves into particles, atoms, molecules, cells, plants, animals, and higher hierarchical levels, its capacity for recognition becomes more pronounced and

expansive. Matter isn't inert as envisioned by Descartes and Newton's mechanical worldview; it's an active entity self-organizing through information.

Since its inception, the universe has branched forces like gravity, electromagnetism, weak and strong interactions, creating elementary particles, atoms, molecules, crystals, and organic matter, culminating in the emergence of life. Information has played a significant role in this process of material evolution. The universe hasn't merely self-organized from simplicity to complexity through matter and energy alone but also through information providing order, form, and structure to matter. Both matter and the universe evolve and become more complex through information.

The universe isn't just an ocean of energy but also an ocean of information. Information originates and propagates throughout every part of the universe. Without information creation, the formation of order would be impossible. Elements of the universe determine their own futures through information. For example, whether a star experiences the shockwaves of a supernova explosion is a crucial piece of information for its future, potentially leading it down different paths, altering its form.

Thus, the processes of the universe are irreversible, asymmetric, and indeterminate. Every element of the universe is interconnected, with information playing the crucial role of connecting them. The universe continually generates and evolves through information. From the material world to the realm of life, no world allows for the exchange of information and recognition processes among objects to be deciphered purely through mechanistic views.