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Ordered Complexity from Dissipative and Chaotic Systems, Including the human brain and society and the Universe; Relevance of the Second Law of Thermodynamics

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Abstract:- The paper connects the characteristics of a dissipative system, which operates far from equilibrium, a chaotic system , depending upon initial conditions and complexity, which forms from the holistic connection of its parts .Consequent, the human brain, human society and the universe itself are portrayed as dissipative, chaotic and complex. Chaos is everywhere as is complexity. The paper analyzes the aspects of nonlinearity in system dynamics based on the ideas of Ilya Prigogine and attempts to forge a link between the systems discussed . The Second Law of Thermodynamics involving the total increase in entropy is elucidated as being universal and inherent in all events of the universe. The law may be considered as part of the evolutionary tool in the formation of complex organisms, galaxies and life itself. Chaotic phenomena are considered in forming, through bifurcation points, un⁹predictable yet deterministic complex systems .The universe is strikingly similar in its structure to the human brain and follows the sequence from dissipative state to complexity and order through chaos .For the Second Law of Thermodynamics to be valid universally, the universe is proposed to be an open system. Furthermore it would be governed by intelligence.

I. DISSIPATIVE STRUCTURES

Dissipative structures are open Thermodynamic systems that maintaintain themselves in a stable state far from equilibrium. Examples in everyday life include convection, turbulent flows ,cyclones, hurricanes and living organisms .Less common instances include lasers , Benard cells, droplet clusters and the elusive Zhabotinsky reactions.[1]

Ilya Prigogine coined the name " dissipative structures" in the 1970s for complex structures created by irreversible processes.

Non equilibrium and non linearity in dissipative structures, especially living systems

A living system is characterized by continual flow and change in its equilibrium, a process which requires thousands of chemical reactions. When these processes come to a standstill, they induce chemical and thermal equilibrium, which also signifies a dead organism. Living organisms continually maintain themselves in a state far from equilibrium, which is a state of life.

Although far from equilibrium , the state is stable and over long periods of time. In spite of the ongoing flow of components, the same structure is maintained .

To describe systems far from equilibrium, Prigogine realized that classical thermodynamics was inappropriate, since its mathematical structure was linear. In such a model, the system evolves towards a stationary state by minimizing "fluxes", which are weak forces existing close to equilibrium. Thus here the system stays as close to equilibrium as possible .Generation of entropy in classically modeled systems is minimal. As a result, the flow process can be expressed by linear equations.

The situation, however, changes drastically when a system is further away from equilibrium.[2] The entropy increases, and the system is no longer close to equilibrium. However, it may encounter new instabilities which lead to novel forms of order. Thus , far from equilibrium, dissipative systems may acquire forms of ever increasing complexity.[1,2]

When the system resides far from equilibrium, its flow processes are interlinked through feedback loops , resulting in equations which are nonlinear . The further a system is from equilibrium, the greater is the complexity and the degree of nonlinearity.

To establish the crucial link between non linearity and non equilibrium, Prigogine and his collaborators developed a Thermodynamics which was nonlinear for systems far from equilibrium , adopting the techniques of dynamical systems theory, the new mathematics of complexity .

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Prigogine realized that the linear equations in classical Thermodynamics could be analyzed in terms of point attractors. Irrespective of initial conditions , the system will be attracted to a stationary state , close to equilibrium, of minimum entropy and its behavior will be completely predictable . Quoting Prigogine, " a system in its linear state tends to forget its initial conditions.

In the nonlinear region, however, the system's behavior is entirely different. Nonlinear equations have more than one solution .The higher the nonlinearity, the more the number of solutions .At any moment new situations may develop. In mathematical language , a bifurcation point is encountered by the system, from which it may branch off to an entirely new state. At the bifurcation point, the system depends on its previous history , as well as initial conditions.

Prigogine's theory further shows that the behavior of a dissipative structure straying far from equilibrium does not follow any universal law any longer . It is unique to the system .Thus the system proceeds to richness and variety. This is a well known characteristic of life .

Indeterminacy also becomes part of Prigogine's theory. At the bifurcation point the system is able to 'choose' between different paths or states depending on its history and different external conditions and can never be predicted over a long range. At each bifurcation point there exists a random entity.

- *Chaos theory and unpredictability*

At the bifurcation point the unpredictability can be explained by elements of chaos theory . Chaos implies that a small change in the system can result in very large differences in the system's behavior .[3]The butterfly effect has become one of the most popular images of chaos. The mathematical version of this property is known as sensitive dependence . Once a path is chosen, the system settles to a pattern which is known as an attractor .[4] The onset of chaos is observed at the bifurcation, appearing as little pieces of order, ephemeral in their instability, with a deterministic and periodic behavior.[5] Genetics, fluid dynamics , weather, economics display chaos, which is ubiquitous and structured. There is reason to believe that complicated systems, traditionally modeled by difficult differential equations, can be understood by discrete and easy maps.

- *Complexity and chaos as a comparative study linked to dissipative systems* .

Complexity theory involves complex systems consisting of interacting parts which often give rise to unexpected order. Chaos theory seeks an understanding of stable systems including numerous interacting parts which may change in a sudden and unexpected or irregular manner.[6]

Complexity arises from relationships such as nonlinearity, emergence, spontaneous order, adaptation and feedback loops, [7] Complex systems are everywhere and are limited in scope and size, cells, people, robots , economies, ecosystems, social networks, diseases , etc.

Complex systems can result from evolving dissipative systems , arising through bifurcation points governed by chaos .[8]

- *From Darwinian evolution to the arrow of time*

Assuming Darwin's version of nature, it can be stated that somehow the biosphere propels itself to evolve into more complex and self organized structures , diverse biological organisms and systems (autopoiesis) .Unicellular organisms gave rise to multicellular organisms, which diverged, differentiated, became more organized and obtained more complexity, In the process, they required additional energy and information to sustain themselves (phylogenesis) . This implies an outright disobedience of the second law of thermodynamics . The earth's biosphere is an island in an entropic stream and indulges in the process of self regulation and evolution , and produces intelligence .

Cybernetics has now supplanted the crude idea of Darwinian evolution through the new science of information .The human brain, intelligence or mind is imbued with the capacity to artificially nurture it's own evolution (anagenesis) and that of the society or environment in which it dwells , through artificial intelligence, neurophysiology, cognitive science and genetic manipulation, using a complex feedback loop.[9] In short, we have gained the knowledge and information to make ourselves smarter. The science of chaos, which is comparatively new , has emerged in the process of autopoiesis and furthers intelligence .Thus a holistic fusion of structure, organization and process, in autopoiesis, phylogenesis, autogenesis and anagenesis, can be surmised as enhancing the evolution process of the human brain and human society.

Macroscopic interactions as opposed to microscopic interactions are subject to entropy, which is irreversible. The latter sets an arrow of time , moving things along in one direction. The heart ticks to the moment it will eventually stop. We grow old and die.

Every chemical reaction is deemed an irreversible process. Every thought of ours iis an irreversible process. We cannot conceive life without considering irreversible processes. Cosmology and the universe can only be formulated using irreversible processes.

Whereas two body problems can be solved by time reversible laws, the three body or many body problem can be understood primarily by incorporating irreversibility. It also goes without saying that we include the arrow of time by extending the laws of classical and quantum mechanics, introducing nonlinearity and chaos theory in dissipative systems. At the points of bifurcation the system chooses from many paths that lead to novel spacetime structures, through evolution. It also introduces certainty, ushering in probability. Examples occur in human history and behaviors in ants.At present we, at a point of bifurcation, have focused on the path of information technology, which shall lead to a novel future a d society. Thus the arrow of time, though unpredictable leads to new situations in the universe , in the earth with humans and human society . And furthermore, using the same logic, it leads to the evolution of the human brain.

- *The human brain and human society are complex dissipative systems.*

The visualization of a complex structure such as the brain is modeled as a complex cellular system with nonlinear dynamics . Mental states such as pattern recognition , feelings and thoughts can be explained by understanding the evolution of parameters (of macroscopic order) of cerebral assemblies which are caused by nonlinear and microscopic interactions of neural cells in learning strategies far from equilibrium , which signifies a dissipative structure .

Consciousness of human society's well as self consciousness and even our dreams are governed by nonlinear dynamics .

- *The Universe as a dissipative , chaotic and complex system*

Scientists have realized since the mid 20th century that we live in a chaotic and complex universe that, in many ways, is completely unpredictable. Embedded within the chaos however, are surprising patterns , patterns that , if we are able to understand them , might lead to deeper revelations .

Chaotic systems are everywhere .As a matter of fact, they dominate the universe. If we stick a pendulum at the end of another pendulum, we have a chaotic system.The population of a species over a period of time is a chaotic system .Chaos is ubiquitous. It is everywhere.

The sensitivity to initial conditions implies that , with chaotic systems, it is not possible to make firm predictions. Even the smallest of deviations can, after some time, result in the system behaving entirely differently. Thus it is impossible to perfectly predict such systems, for example, the weather.

Some systems manifest a set of patterns called attractors . This means that no matter what the initial conditions are , the system settles to a pattern that is favorable to it. Thus new order and variety evolves.

Life is the result of such an order. The varieties and specifics of different organisms and also the varieties and order of different stars and galaxies must be a result of these patterns . They also result in fractals, which are self similar, that is , small patterns within the larger pattern which are alike .The weather pattern , since it is a fractal conceived prescribed pattern, which is repetitive, with smaller scales to infinity is strange, and is known as a strange attractor .

Order is thus a natural result of chaos.Chaos can produce order adversely as it produces randomness.Chaos proceeds as a pattern .All that one requires is to find that pattern and in that way, order can be created out of disorder. In every chaotic production, one can trace order.

- *The Second Law of Thermodynamics and entropy revisited*

The Second Law of Thermodynamics , which regulates changes in order, requires disorder or entropy to always increase. However, the development of life is a classic example of order on the increase. A complex system is the epitome of such order, yet obtained from dissipative systems and the onset of chaos which introduce disorder. Since living systems, as well as the human brain and society and suffice to say, other solar systems , galaxies and the universe.have evolved from past history , into even more complex and elaborate forms, we might note that the level of order has risen. To maintain the Second Law, then, the formation of order or complexity must be accompanied by dissipation of energy.The dilemma can possibly be solved if the universe is considered to be an open system, rather than the traditional concept of it being a closed one.

The universe as an intelligence compared to the neuronal network in the brain

The human brain is a complex, multilayered structure in time and space in which cellular, molecular and neuronal characteristics exist together.

The universe is a cosmic web built primarily with building blocks of self gravitating dark matter and dark energy in the form of halos .

In such space, ordinary matter has collapsed to form galaxies (and all stars in them) .

Whereas the brain is 77% water , the universe is 73% dark energy. Whereas the universe is mainly formed by gravity the brain is formed by biology.[10]

.Galaxies cluster together, with filaments, sheets of matter and voids , strikingly similar to the human brain. While the scale is certainly different the structures are similar. In a comparative study, it has been found that 69 billion neurons in the human brain function similar to the 100 billion galaxies in the universe.[11]

Order, that develops everywhere in the universe , and , parallely in the brain result from dissipative conditions , propelled by chaos and culminating in organized complexity . Thus possibilities may be conjectured of an universal intelligence, governing the laws of the universe and the consequent order.

II. CONCLUSION

Links between dissipative structures and complexity and order is achieved through bifurcation propelled by chaos. The Second Law of Thermodynamics , with increase in entropy and disorder , finds a dilemma with inherent order being formed in the evolution of the universe .The paradox may be solved by proposing the universe to be an open system. The universe , in its structure, has been analyzed to largely resemble the structure of the human brain and its neuronal network. Thus the universe may be conjectured as consisting of an intelligence governing the laws producing order.

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