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Natural emergence

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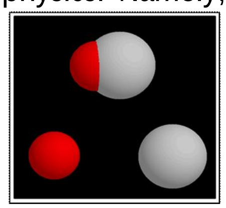
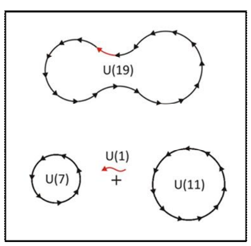
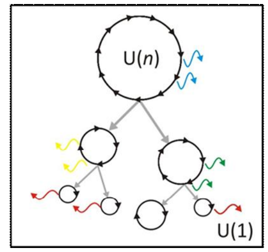
I must say I admire the courage of the program committee to allow a talk on emergence because I believe that also many of you see no problem, no puzzle about emergence, but find it only natural that the properties of a complex system cannot be reduced to the properties of its simple constituents. For example, the properties of our neural network in the brain seem irreducible to the properties of neurons, and also the properties of a molecule cannot be reduced to the properties of its constituent atoms. This conclusion about irreducibility follows directly from the foundations of physics. Namely, according to Emmy Noether's theorem any system can be described in terms of action which integrates all flows of energy along their paths.



When flows of energy circulate on closed trajectories, the system is stationary and its action can be related to a group of symmetry. Conversely, when a flow of energy breaks open, the system will change from one state to another. The action will change at least by one quantum. It is the photon that is either absorbed from the surroundings to the system or emitted from the system to its surroundings.

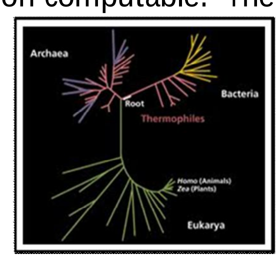


For example, when atoms react to form a molecule, heat will be either absorbed or emitted. A change of state is a change in energy, so eigenvalues and eigenmodes that relate to the system's properties and motions will also change. Conversely, it would violate conservation of energy if any one new quality were to materialize from mere multiplicity, i.e., from constant-energy permutations of pieces. Therefore dissipation is innate in the emergence of new characteristics just as it is in the disappearance of old ones. The photons, as flows of energy, are literally inter-actions, between the constituents. The resulting systemic interdependence among its constituents is sometimes referred to as supervenience.



When quanta are integrated from the surroundings to the system, the emerging entirety will indeed be greater than the prior sum of free constituents. By the words of Sir Arthur Eddington We often think that when we have completed our study of one, we know all about two, because "two" is "one and one." We forget that we still have to make a study of "and.", – which is the photon. It is the dissipation that makes the difference between emergence and extrapolation. There is no need to classify phenomena to strong or weak emergence but there is all the need to classify systems to those that are stationary in energy and to those that are evolving in energy.

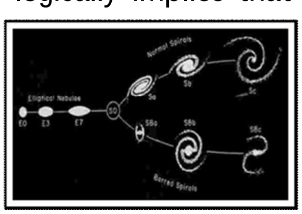
All this is of course trivial and therefore fundamental. To understand emergence as a dissipative process from one state to another, is to understand evolution as a spontaneous symmetry breaking process from one action to another. When there are alternative paths for energy dispersal, evolution is a path-dependent process. Since the flows of energy and their driving forces are inseparable, the process is intractable, i.e., non-computable. The derivates at the branching points are inexact. However, natural processes are not random processes but consume free energy in least time.



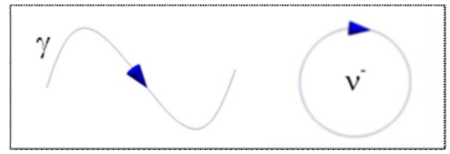
This guiding imperative for the flows of energy is given by the variational principle in its original form by Pierre-Louis Moreau de Maupertuis from 1744 where the integrand is kinetic energy as introduced by Emilie du Châtelet few years earlier. The form applies also for a stationary state to which evolution will arrive when all free energy has been consumed. The familiar Euler-Lagrange-Hamilton form is for models that deliberately deny any change of state.

Here on Earth circumstances are somewhat special because the surrounding energy density due to the sunshine is higher than that bound in the global system. Biota has emerged and evolved to level off this difference. Over the eons the flows energy themselves have naturally selected increasingly more effective energy transduction paths and mechanisms usually referred as the species to consume the free energy in least time. According to the principle of least action a newly emerged characteristic is valued only as a means of energy transduction. Mechanisms, inanimate just as animate, will thrive when diminishing energy differences between the system and its surroundings. Those that will consume free energy in the least time are the fittest. Thus complexity as such is no end itself, but an energy transduction network will organize itself from available ingredients and influx to a complex system when that is effective in executing the simple principle to decrease energy differences with respect to its surroundings in the least time. Ingredients and influx govern the distribution of assets.

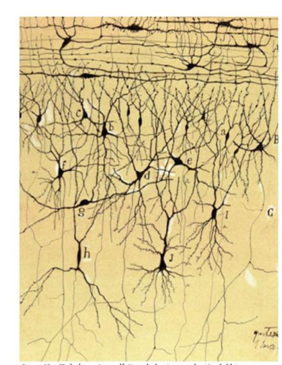
In the Universe as a whole the energy dense bound forms are progressively broken down to attain the equilibrium with the zero-density surroundings. Mechanisms of dissipation stars and others have evolved over the eons to propel to the universal system toward the final destination, the action at the lowest group of symmetry, U(1) that characterizes electromagnetic radiation. Conversely, the notion of heat death logically implies that everything that exists is ultimately composed of integral number of photons, the most elementary action.



When a photon as an open action wraps itself to a closed ring, it becomes a neutrino. When an array of photons wraps to a torus, the closed geodesic is identified by the generated charge, mass and magnetic moment to the electron. Since quarks carry integer fractions of elementary charge, protons and neutrons are understood as closed actions where quarks are glued together by these short wavelength photons to a tetrahedral coordination that will account for charges, masses and magnetic moments of the nucleons.



When the principle of emergence from photon to particles is clear at the bottom, the same principle will account also for all systems higher up in the hierarchy of nature. For example, a neural network can also be considered as an energy transduction system that is characterized by some individually distinct action that integrates all signals as flows of energy along their neural pathways across synapses. When this simple message about actions as entities of nature is absorbed, lucid lines of thinking will emerge. When these lines of reasoning are found more effective in comprehending nature, they will be naturally selected as the least-action pathways by the signals themselves.


Capas 1ª y 2ª de la corteza olfativa de la circunvolución del hipocampo del niño, n. 1901 © Herederos de Ramón y Cajal

These thoughts have not emerged in isolation but from conversations with my many colleagues. Thank you, thank you very much for your attention.