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Emergence

Information philosophy explains the reality of emergence, because what emerges is *new information*. The universe began with minimal information. For hundreds of thousands of years, the only information structures were fundamental particles. These were only the simplest matter and energy, and they are *conserved quantitities*. In a *deterministic* universe, that initial information would be all the information in the universe today and in the future, because information would be conserved.

But information is not conserved. Because it is neither matter not energy, information is *immaterial*. Matter can be converted to energy ($E = mc^2$), but their total is a constant. The only thing that is new is information. *Information is the only emergent*.

A complex physical world of galaxies, stars, and planets has emerged, a diverse biological world has emerged, and a mental world of ideas has emerged, including the *idea of emergence* itself. Emergence is the result of the **cosmic creation process**.[1]

And this process is fundamentally a rearrangement and transformation of the fundamental particles of matter and energy.

The basic idea of emergence is that there are properties - perhaps even "laws" - at the upper hierarchical levels of nature that are not derivable from or reducible to the properties and laws of the lower levels. Thus chemistry has properties not derivable from physics, biology has properties not derivable from chemistry, and psychology has properties not derivable from biology.

Emergence or Reduction?

Reductionism, by contrast, argues that everything can be explained by (reduced to) the basic laws of physics. The world is said to be "causally closed." "Physicalism" is the idea that everything that is caused has a physical cause, that everything that happens is caused by material particles in motion

Causal control is assumed to work "bottom-up." The motions and forces between the material particles are said to determine

1 See appendix F.

everything chemical, biological, and psychological. Information theory would then require that the information content of everything being done at the higher biological and mental levels is actually contained in the structure and motions of the atoms and molecules. We shall show that this reductionism is implausible

Causal closure implies that every thought in the mind is somehow present in the paths or positions of the atomic particles themselves. Mental causation is then redundant. Mental events are epiphenomenal, non-existent, just an illusion.

Genuine emergence of new properties at the higher biological and psychological levels, on the other hand, requires that those properties can exert "top-down" causal control on the motions of particles in lower levels. This is the notion of *downward causation*, the highest version of which is mental causation.[2] It means motions of the atomic particles must effectively be controlled by the mind, which strikes many biologists and psychologists, who are uncomfortable making claims about physics, as extravagant.

If the laws of nature control everything in the visible universe, they say, how can they fail to control the mind?

Proving this "top-down" or mental causation is made doubly difficult, since we would like to show that "bottom-up" causes on the body and mind can somehow be blocked. It seems illogical or even impossible to show that causation can flow downward but not upward.

But we can demonstrate emergent phenomena at the biological and mental (neural) level that have exactly this emergent property of what we can call "one-way causality."

History of the Idea of Emergence

The idea of emergence was implicit in the work of John Stuart Mill and explicit in the work of "emergentists" like George Henry Lewes, Samuel Alexander, C. Lloyd Morgan, and

2 See chapter 15.

C. D. Broad. Some wanted to explain the direct emergence of mind from matter, to solve the mind-body problem, but as Alexander put it, there are at least two distinct steps - mind emerges from life, just as life emerges from the physical-chemical.

Mill discusses the Laws of Nature in his System of Logic, Book III. Although Mill did not use the term "emergent," he makes the concept clear enough:

> The chemical combination of two substances produces, as is well known, a third substance with properties different from those of either of the two substances separately, or of both of them taken together. Not a trace of the properties of hydrogen or of oxygen is observable in those of their compound, water. The taste of sugar of lead is not the sum of the tastes of its component elements, acetic acid and lead or its oxide; nor is the colour blue vitriol a mixture of the colours of sulphuric acid and copper...If this be true of chemical combinations, it is still more true of those far more complex combinations of elements which constitute organized bodies; and in which those extraordinary new uniformities arise, which are called the laws of life... To whatever degree we might imagine our knowledge of the properties of the several ingredients of a living body to be extended and perfected, it is certain that no mere summing up of the separate actions of those elements will ever amount to the action of the living body itself.[3]

Lewes also used Mill's example of the properties of water not being reducible to those of oxygen and hydrogen. He coined the term "emergent" in 1875:

> Although each effect is the resultant of its components, the product of its factors, we cannot always trace the steps of the process, so as to see in the product the mode of operation of each factor. In the latter case, I propose to call the effect an emergent. It arises out of the combined agencies, but in a form which does not display the agents in action.[4]

In his 1920 book *Space, Time, and Deity*, Samuel Alexander cited Lloyd Morgan as his source of emergentism, and wrote:

> much of what I have to say has been already said by Mr. Lloyd Morgan in the concluding chapter of his work on Instinct and Experience. The argument is that mind has certain specific characters to which there is or even can be no neural counterpart...

3 *A System of Logic*, Book III, chapter VI
4 *Problems of Life and Mind*,(1875), vol. 2, p. 412

> Mind is, according to our interpretation of the facts, an 'emergent' from life, and life an emergent from a lower physico-chemical level of existence.[5]

Later, in his 1922 Gifford Lectures and 1923 book *Emergent Evolution*, Lloyd Morgan saw even atoms and molecules as emergent entities and introduced the related "top-down" concept of hierarchical *supervenience*:

> ...in the physical world emergence is no less exemplified in the advent of each new kind of atom, and of each new kind of molecule. It is beyond the wit of man to number the instances of emergence. But if nothing new emerge - if there be only regrouping of pre-existing events and nothing more - then there is no emergent evolution.
>
> Under emergent evolution there is progressive development of stuff which becomes new stuff in virtue of the higher status to which it has become raised under some supervenient kind of substantial gotogetherness.[6]

Vitalists like Henri Bergson and Hans Driesch may not have used the term emergence, but they strongly supported the idea of teleological (purposeful), likely non-physical, causes, without which they thought that life and mind could not have emerged from physical matter.

C. D. Broad's view of the mind was emergentist and vitalist.

But Broad distinguished between what he called "Substantial Vitalism" (a dualist theory of an immaterial substance as a vital force, for example, Bergson's *élan vital*) and what Broad called "Emergent Vitalism" (some kind of non-reductive materialism, in which the vital property emerges from the body, and in the case of mind, from the highest bodily level - the brain).

Broad says he borrowed the adjective "emergent" from Lloyd Morgan and Alexander.

Broad contrasted the two forms of Substantial and Emergent Vitalism with what he called "Biological Mechanism," which is essentially a reduction of biology to physics and chemistry. All the emergentists were of course anti-mechanists or anti-reductionists.

5 *Space, Time, and Deity* (1920), vol. 2, p. 14
6 *Emergent Evolution* (1923), pp. 1-6

Broad also mentioned Driesch, an anti-mechanist who developed a sophisticated form of vitalism that he called "neovitalism."

Driesch saw clear evidence of a kind of teleology in the ability of lower organisms to rebuild their lost limbs and other vital parts. He used Aristotle's term "*entelechy*" (loosely translated as "having the final cause in") to describe the organism's capacity to rebuild itself. Driesch said this disproved the theory of *preformation* from a single original cell. Driesch studied the original cells of a sea urchin, after they had divided into two cells, then four, then eight. At each of these stages, Driesch separated out single cells and found that the separated cells went on to develop into complete organisms. This is regarded as the first example of biological cloning.

Broad rejected Driesch's idea of *entelechy* as a non-material, non-spatial agent that is neither energy nor a material substance of a special kind, but we should note that Driesch's entelechy well describes the information content of any cell by which it develops into a complete organism. Driesch himself maintained that his entelechy theory was something very different from the substance dualism of older vitalisms. So what was Broad's criticism of Driesch? Neither thinker could produce a clear description of their vital element.

Broad was sophisticated in his discussion of emergence. He saw that the kind of emergence that leads to water and its unique chemical properties, when compared to the properties of its molecular components hydrogen and oxygen, has no element of purpose or teleology. The emergence of life (and mind) from physics and chemistry, however, clearly introduces a kind of design or purpose. Modern biologists call it *teleonomy*, to distinguish it from a metaphysical *telos* that pre-exists the organism. It comes as an essential part of the organism.

It seems likely that both Driesch and Broad were trying to grasp this teleonomy, which can be simply described as the built-in purpose of each living cell to replicate its information. "The goal of every cell is to become two cells."

Three Kinds of Information Emergence

Note there are three distinct kinds of emergence, at the material, biological, and mental levels:

1. the *order out of chaos* when the randomly distributed matter in the early universe first gets organized into information structures.

This was not possible before the first atoms formed about 400,000 years after the Big Bang. Information structures like the stars and galaxies did not exist before about 400 million years. As we saw, gravitation was the principal driver creating information structures.

Nobel prize winner Ilya Prigogine discovered another ergodic process that he described as the "self-organization" of "dissipative structures." He popularized the slogan "order out of chaos" in an important book.[7] Unfortunately, the "self" in self-organization led to some unrealizable hopes in cognitive psychology. There is no self, in the sense of a person or agent, in physical phenomena like convection cells and whirlpools.

Both gravitation and Prigogine's dissipative systems produce a purely physical/material kind of order. The resulting structures contain information, with a "steady state" flow of information-rich matter and energy through them. But they do not process or communicate information. They have no purpose, no "telos."

Order out of chaos can explain the emergence of downward causation on their atomic and molecular components. But this is a gross kind of downward causal control. Explaining life and mind as "complex adaptive systems" has not been successful. We need to go beyond "chaos and complexity" theories to *teleonomic* theories.

2. the *order out of order* when the material information structures form self-replicating biological information structures. Some become information processing systems.

7 *Order Out of Chaos*. Shambhala, 1984.

In his famous essay, "What Is Life?," Erwin Schrödinger noted that life "feeds on negative entropy" (or information). He called this "order out of order."

This kind of biological processing of information first emerged about 3.5 billion years ago on the earth. It continues today on multiple emergent biological levels, e.g., single-cells, multi-cellular systems, organs, etc., each level creating new information structures and information processing systems not reducible to (caused by) lower levels and exerting downward causation on the lower levels.

And this downward causal control is extremely fine. Biological systems control the motions and arrangements of individual atoms and molecules.

Biological systems are cognitive systems, using internal "subjective" knowledge to recognize and interact with their "objective" external environment, communicating meaningful messages to their internal components and to other individuals of their species with a language of arbitrary symbols, taking actions to maintain themselves and to expand their populations by learning from experience.[8]

With the emergence of life, "purpose" also entered the universe. It is not the pre-existent "teleology" of many idealistic philosophies (the idea of "essence" before "existence"), but it is the "entelechy" of Aristotle, who saw that living things have within them a purpose, an end, a "telos." To distinguish this evolved telos in living systems from teleology, modern biologists use the term "teleonomy."

3. the pure *information out of order* when organisms with minds generate, store (in the brain), replicate, utilize, and then externalize some non-biological information, communicating it to other minds and storing it in the environment. Communication can be by hereditary genetic transmission or by an advanced organism capable of learning and then teaching its contemporaries directly by signaling, by speaking, or indirectly by writing and publishing the knowledge for future generations.

8 See appendix G on Biosemiotics.

> This kind of information can be highly abstract mind-stuff, pure Platonic ideas, the stock in trade of philosophers. It is neither matter nor energy (though embodied in the material brain), a kind of pure spirit or ghost in the machine. It is a candidate for the immaterial dualist "substance" of René Descartes, though it is probably better thought of as a "property dualism," since information is an immaterial property of all matter.

The information stored in the mind is not only abstract ideas. It contains a recording of the experiences of the individual. In principle every experience may be recorded, though not all may be reproducible/recallable. Information philosophy claims that everything created since the origin of the universe over thirteen billion years ago has involved just two fundamental physical processes that combine to form the core of all creative processes at all three levels.[9]

This core creative process underlies the formation of microscopic objects like atoms and molecules, as well as macroscopic objects like galaxies, stars, and planets. (Note that the formation of self-organizing material systems in conditions far from equilibrium that are the subjects of chaos and complexity theories are this basic, non-teleonomic form of emergence.)

With the emergence of teleonomic (purposive) information in self-replicating systems, the same core process underlies all biological creation. But now some random changes in information structures are rejected by natural selection, while others reproduce successfully.

Finally, with the emergence of self-aware organisms and the creation of extra-biological information stored in the environment, the same information-generating core process underlies communication, consciousness, free will, and creativity.

The physical processes in the core creative process are quantum cooperative phenomena (involving the mysterious "collapse" of the wave function necessary for the appearance of particles - see chapter

9 See appendix F for details on the cosmic creation process

20) and thermodynamics, which requires the transfer of entropy away from newly emergent information structures to ensure their stability.[10]

Emergence in the Body

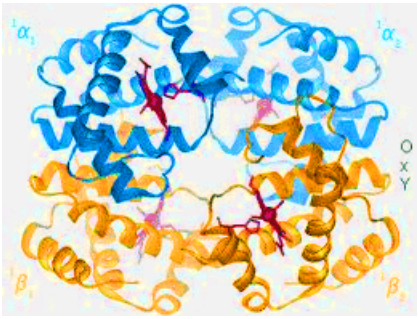

Figure 27-32. Four protein chains of hemoglobin.

When a ribosome assembles 330 amino acids in four symmetric polypeptide chains (globins), each globin traps an iron atom in a heme group at the center to form the hemoglobin protein. This is *downward causal control* of the amino acids, the heme groups, and the iron atoms by the ribosome. The ribosome is an example of Erwin Schrödinger's emergent "order out of order," life "feeding on the negative entropy" of digested food.

When 200 million of the 25 trillion red blood cells in the human body die each second, in each of the new cells 100 million hemoglobins cell must be assembled. With the order of a few thousand bytes of information in each hemoglobin, this is 10 thousand x 100 million x 200 million = 2×10^{20} bits of information per second, a million times more information processing than today's fastest computer CPU. Red blood cells are 25% of body weight. Twenty percent of these are working in the brain to support mental information processing.

When a ribosome produces a protein that does not fold properly, a chaperone enzyme, shaped like a tiny trash can, opens its lid and captures the protein. It then closes the lid and squeezes the protein. Upon release, the protein then frequently folds properly. If it does not, the chaperone captures it again and disassembles it back to its amino acids. The chaperone is an emergent agent that is in no way the result of "bottom-up" processes from its amino acid components. It is also an extraordinary example of biological error detection and correction.

10 See appendix B on entropy and the second law

Emergence in the Brain

When a single neuron fires, the active potential rapidly changes the concentration of sodium (Na+) ions inside the cell and potassium (K+) ions outside the cell. Within milliseconds, thousands of sodium-potassium ion channels in the thin lipid bilayer of the cell wall must move billions of those ions from one side to the other. They do it with emergent biological machinery that exerts downward causation on the ions, powered by ATP energy carriers (feeding on negative entropy). Random quantum indeterministic motions of the ions put some near the pump opening, where quantum collaborative forces capture them in a lock-and-key structure.[11]

When many motor neurons fire, innnervating excitatory postsynaptic potentials (EPSPs) that travel down through the thalamus and the spinal cord and cause muscles to contract, that is as literal as downward causation gets in the body.

When the emergent mind decides to move the body, that mental causation is realized as downward causation.

When an emergent philosopher rearranges and communicates ideas, verbally in lectures, or as written words in a published paper, or as the bits of information in a computer memory, this is "information out of order," ultimately dependent on the body digesting food, producing energy with negative entropy ("order out of order"), but in no way controlled "bottom-up" by the molecules of body or food material, or by the energy consumed.

The Emergence of Immaterial Information Processing

Can information provide the basis for a different kind of mental substance, one that emerged?

Abstract information is neither matter nor energy, yet it needs matter for its concrete embodiment and energy for its communication. Information is *immaterial*.

It is the modern spirit, the ghost in the machine.

Immaterial information is perhaps as close as a physical or biological scientist can get to the idea of a soul or spirit that departs the body at death. When a living being dies, it is the maintenance of biological and mental information that ceases. The matter remains.

11 See "Ion Pumps in Neurons Select Individual Atoms" on page 183

Information philosophy proposes a mind-body dualism in which thoughts (pure information processing) in our minds have genuine causal power over the body. This might be considered a *metaphysical* mind, but it is purely biological and entirely dependent on the brain. There are *multiple realizations* of physical/material "hardware" that can implement the "software" of our ideas.

For example, when one person teaches another some new technique, or transmits some purely intellectual knowledge, the other person is another physical realization, different hardware now running the same software.

To make this case, we need to establish the following:

• that the information in a mind can be regarded as an *immaterial* substance.[12]

• that the information in a mind, while dependent on the body, has genuine causal (adequately determined) power over the body.[13]

• that the information in a mind has not been pre-determined by the sum of genetic inputs and life experiences, but has at least in part been created by the agent, with inputs from some indeterministic processes.[14]

The Emergence of Determinism

When small numbers of atoms and molecules interact, their motions and behaviors are indeterministic, governed by the rules of quantum mechanics. But when large numbers of particles gather into large material objects, they are statistically determined. This is called the "quantum to classical transition."

Werner Heisenberg's principle of indeterminacy (mistakenly called "uncertainty," as if the problem is epistemic/subjective and not ontological/objective) gives us the minimum error in simultaneous measurements of position x and momentum p, for any object, large or small,

$$\Delta p \, \Delta x \geq h,$$

where h is Planck's constant of action.

12 See appendix A on information
13 See chapter 16 on mental causation
14 See chapter 4 on the two-stage model of free will.

To see how "adequate" determinism emerges for large numbers of particles, note that the momentum $p = mv$ (the product of mass and velocity), so we can write the indeterminacy principle in terms of velocities and positions as

$\Delta v \, \Delta x \geq h / m$.

When large numbers of microscopic particles get together in massive aggregates, the mass increases and h / m approaches zero, the indeterminacy of the individual particles gets averaged over and macroscopic "adequately" deterministic laws "emerge." The positions and velocities of large massive objects can therefore be "determined" to a high degree of accuracy, in fact beyond our ability to measure.

Determinism is thus an emergent property for an object made up of large numbers of material particles,.

The "laws of nature," such as Newton's laws of motion, are all statistical in nature. They also "emerge" when large numbers of atoms or molecules get together. For large enough numbers, the probabilistic laws of nature approach practical certainty. But the fundamental indeterminism of component atoms never completely disappears.

There Was a Time with No Determinism

So determinism "emerges" today from microscopic quantum systems as they become a part of larger and more classical systems. But we can say that determinism also emerged in time. In the earliest years of the universe, large massive objects did not yet exist. All matter was microscopic and quantal.

We can now identify that time in the evolution of the universe when determinism first could have emerged. Before the so-called "recombination era" at about 380,000 years, when the universe cooled to a few thousand degrees Kelvin, a temperature at which atoms could form out of sub-atomic particles (protons, helium nuclei, and electrons), there were no "macroscopic objects" to exhibit deterministic behavior.

The early universe was filled with positive ions and negatively charge electrons. The electrons scattered light photons, preventing them from traveling very far. The universe was effectively opaque past very short distances. When the temperature fell to about 3000 degrees K, the charged particles combined to form neutral atoms (hydrogen and helium). With the scattering electrons now bound into atoms, the photons suddenly could "see" (travel) to enormous distances. This produced the transparent universe that we take for granted today (on cloudless nights).

Those 3000 degrees K photons have been red-shifted as a result of the universe expansion and now appear to us as the 2.7 degree K "cosmic microwave background" radiation left over from the big bang. We are looking at a moment in time when "classical" objects obeying apparently deterministic causal laws did not yet exist.

After a few hundred million years, large material objects could begin to form. Only then could anything "classical"" or "deterministic" come into existence, could "emerge."

Emergence Denied

Some prominent philosophers of science, logical empiricists who were committed to the ability of physical science to explain everything as "unified science," were confident that "emergence" would go the way of "holism" and "vitalism."

For example, the former member of the Vienna Circle and leading reductionist Herbert Feigl wrote in 1958:

> Inseparably connected with holism and the Gestalt philosophy is the doctrine of emergence. This is indeed my own, admittedly risky and speculative, guess; that is to say, I believe that once quantum dynamics is able to explain the facts and regularities of organic chemistry (i.e. of non-living, but complex compounds) it will in principle also be capable of explaining the facts and regularities of organic life.[15]

15 "The 'Mental' and the 'Physical'", in *Concepts, Theories, and the Mind-Body Problem*, Minnesota Studies in the Philosophy of Science, vol.2, p. 414