# The How and The Why of Emergence and Intention

By George Gantz

## Introduction:

Over the past few decades, considerable progress has been made in explaining how complex, intelligent behaviors emerge in dynamic systems. The overall architecture can now be discerned, although much work remains to be done on the particulars.

At the same time, the question of why the universe works this way remains as elusive as ever. The trajectory of emergent cascades is not predictable. It appears as if choices are being made leading to particular outcomes and not others. There is a direction to the process, and we do not understand the nature of that intentionality.

We are left with contradictory hypotheses for why the universe is the way it is. Do you believe that what exists is fundamentally an expression of randomness within mathematical forms? If this is the case, then you would argue that intentionality is an epiphenomenal illusion and that our place in the multiverse is a coincidence.

Or do you believe in a cosmic intentionality that provides generative guidance for the emergence and evolution of our uniquely specified universe? If this is the case, you might argue that we are here in this world as a consequence of and consistent with some purposeful process.

I believe this question is, and always will be, from an empirical standpoint, undecidable. Yet our choice of an answer is fundamental to how we think about the world and how we live in it. We had best choose wisely. I make an argument for cosmic intentionality.

## Prelude:

I was very fortunate, recently, to see a large flock of starlings take flight. Within seconds, the flock organized into a coherent but flexible spheroidal shape that swooped, climbed and spiraled in the evening sky. I was mesmerized and baffled by the swirling, beauty. I know the behavior is the result of a network signaling process with each individual bird responding to the movements of its seven neighbors, and I understand the behavior has evolutionary significance as a defensive response to predators. But I wonder --- how do the starlings feel as they dance in the sky? For a short period many decades ago, I raced bicycles. On occasion, I found myself in the center of a racing peloton. For me, that experience was intimate, exuberant and dangerous --- wild and crazy fun.

## Emergence:

According to our modern cosmology, the universe unfolded in a cascade of transitions and broken symmetries from the primordial state of the Big Bang. The emergence of the Higgs field, conveying mass, is one early transition, as are the appearances of the other

fundamental physical forces. This cascade led to the universe of standard particle physics as we know it today. With physics in place, the universe continued its evolution. Atoms formed, with proton-neutron nuclei and clouds of electrons in precise energy states, all behaving in obedience to the laws of physics. Stars began to burn, galaxies coalesced and planetary objects appeared. Elements combined to form complex chemicals that spread throughout the universe.

On at least one planet, Earth, some of those chemicals reacted with others, creating a complex mix of substances. New behaviors appeared, including self-replication, autocatalysis and metabolic processing. Complex colonies of reproducing units began to grow, and cooperative symbiotic behaviors developed. Single celled organisms emerged and evolved into increasingly complex forms. Eventually, mammals and primates appeared, with sophisticated intelligence. Consciousness expanded, enabling reflective capacities in language and tool making. One species, humans, was able to build civilizations and science.

The Second Law of Thermodynamics stipulates that any closed physical system inevitably progresses toward higher entropy states, described in lay terms as increasing homogeneity or "sameness". Release inert gas into a box and it will eventually fill the box in an even distribution, assuming no outside influence. A block of ice melts and becomes a puddle of water. An egg falls and breaks and cannot be reassembled. In each case the original structure has been lost and the material is mixed up. Entropy has increased.

Yet all the interesting structures mentioned above that come into being as the universe evolves, seem to be acting counter to the Second Law. If the universe is running down by transitioning from the low entropy conditions of the Big Bang to states of increasing homogeneity and higher entropy, then where do the remarkable cosmological features of stars and galaxies, the complex phenomena of chemistry and biology, and the capacity for life and human consciousness come from?

The simple answer is that local structure and order emerges by exporting entropy to the larger environment. The examples above are not closed systems. The closed system of the entire universe as a whole continues to run down, possibly towards an icy and inevitable death, but as it does, local pockets of increasing organization and structure emerge. This counter-entropic process is explained in the theory of non-linear dynamic systems. When energy is in flux, stable structures tend to emerge in the otherwise chaotic flow by dissipating energy. When we open the drain at the bottom of a sink the water molecules rush for the drain, bouncing and jostling in a disorganized chaos. As the molecules become organized and dissipate the energy caused by the pull of gravity, in the form of friction to the sink and drain surfaces, a whirlpool emerges. The flowing water seeks out a stable structure that maximizes the efficient local dissipation of energy and local minimization of entropy.

In a similar way, galaxies and snowflakes form in the dynamic chaos of interstellar gas or atmospheric clouds; intricate and beautiful shapes of nearly infinite variety emerge.

Turbulent water produces swirling eddies, dancing waves and shimmering surfaces, order and structure emerging from chaotic dynamic processes. The flocking of birds, in the configuration known as a murmuration, creates a dancing, spiraling pattern. The birds follow simple, instinctive flight rules, but a form of sophisticated intelligence emerges from their behaviors. The flock can foil predators in a way individual birds cannot. Similar emergent intelligence appears in every bee and ant colony. Even the simple sunflower produces a beautifully ordered and structured pattern in its flower. The plant follows the simple energy-minimizing rule of the Fibonacci Sequence (or Golden Ratio) in forming a seed-head that displays multiple interlocking spirals spinning both left and right.

The emergence of structure is the dynamic response through time to the pull of entropy. Whirlpools arise from the pressure of water as it flows through a constriction. Galaxies emerge in response to the force of gravity as matter expands. Intelligence develops from the pressure of replicating systems seeking to thrive in the face of constraints. Energy, matter and information systems respond to this pressure under constraint by flowing within mathematical forms to maximize efficiency and minimize entropy locally. This is how complex, intelligent behaviors emerge in dynamic systems.

## Undecidability:

Imagine 100 monkeys typing (presumably randomly) on 100 typewriters for a limitless period of time. Eventually, hidden somewhere in the seemingly endless streams of nonsense, they would produce a perfect replica of Shakespeare's Hamlet. How can you tell the difference between nonsense and a work of art created intentionally?

Suppose you were to come across an anonymous digitized copy of a (very) large manuscript, and you began to interrogate the data looking for patterns. Among the clearly nonsensical variations, you discover a few rare subsets that appeared to create meaningful phrases in the English language. Probing those subsets, you eventually find the hidden gem of Shakespeare's Hamlet, and you might print it out for amusement. Would you conclude that this is an unusual but totally random coincidence, e.g. the output of a team of typing monkeys? Or would you conclude that the production of this remarkable work of literature, one that had been buried in reams of nonsense, was the product of a literary genius?

Now suppose someone else discovered your printout of the Hamlet that had been produced by the typing monkeys, but without any information about its origin. Would they conclude that a literary genius intentionally produced this remarkable work of literature? Or would they conclude that this is an unusual but totally random coincidence?

Our universe is vastly more wonderful, intricate and complex than Shakespeare's Hamlet, and we do not know why it is the way it is. We are like the third person

discovering a Hamlet manuscript, trying to decide if it was intentionally produced or if it is just an unusual but totally random coincidence. The problem is undecidable.

Consider the number of quantum perturbations in the early history of the universe. This is an immense number, 10^10^10^7 by one estimate[i]. Each of these perturbations represents an inflection point where the trajectory of the universe changed. Under the multiverse theory, each resulted in alternate universes, and our particular universe is merely one trajectory among the exceedingly many. Our existence is contingent on that specific trajectory, but it is simply a random occurrence. Max Tegmark theorizes that the entire multiverse contains infinite sets of universes.[ii] If this is the case, then any specific trajectory within the infinite set has an effective probability of zero.

Consider the alternative theory, one that rejects the multiverse theory and accepts our observational experience of a single universe at face value. Under this theory, one has to conclude that at each quantum inflection point (or at each of the infinite possible points of divergence theorized under the infinite multiverse), a selection was made that guided the universe on its inevitable trajectory towards the state which we are now experiencing. I refer to that hypothetical selection process as a cosmic intentionality.

In the 100 monkeys thought experiment, it is impossible to determine whether your copy of Hamlet was written by monkeys, or by Shakespeare. It is, correspondingly, impossible to determine if this universe was written by randomness or by intention.

Consider the stream of experiences that make up our lives. Many of those experiences seem to be random --- some believe they are all random. But there are many events in individual human lives that are transformational – being born to our parents at a particular time and place; surviving an accident; working hard to achieve an award; meeting a mentor that shapes your career; falling in love; making a decision to try something new; being diagnosed with cancer; having children; experiencing the death of a loved one. In light of who we each turn out to be, such experiences are not accidents but essential features of the trajectory of our life. As some will say, looking back, "this was meant to be."

## Causation:

The common understanding of causation follows a reductionist view: The interactions of the smallest structures cause the macro effects we actually see --- everything flows from past physical states in conformity with the laws of physics. A white billiard ball strikes a red billiard ball causing it to move. This action-reaction event is caused by the physical properties of the billiard balls, properties that are in turn caused by the molecular components of the balls. These components and their behaviors, in turn, are caused by fundamental quantum particle/wave behaviors at the very foundation of the universe. In essence, the smallest structures cause the macro effects we actually see. These effects include all the features of the world as we know it: the stars and galaxies of the cosmos; all the chemical and physical phenomena including biology and

life; the workings of computers; and the workings of the human mind. All of these things are caused by the minute quantum stuff of the universe. Causation is a bottom-up process.

There are flaws in this model of causation. One broad criticism is that bottom-up causation leaves no place for free will, implying that our universe and our lives are stuck on a deterministic treadmill. Determinism denies the possibility that choices can change the way things happen in the physical world. A more narrowly focused critique is that bottom-up causation cannot adequately explain how novel properties and behaviors, such as galaxy formation, life, or consciousness, emerge from the lower-level systems, the stars, organic chemicals, or neural networks.

The argument, offered by physicist Phillip W. Anderson[iii] and others, is that the reduction of causal explanation to fundamental laws does not provide the means to then reconstruct the universe. Each level of complexity leads to entirely new properties not inherent in or predictable from the prior level. He maintains that the hierarchical structure of increasing complexity arises as a function of symmetry breaking, and the resulting whole is more than, and different from, the sum of its parts.

Cosmologist George Ellis addressed the problem in his 2012 FQXi essay.[iv] He theorized that symmetry breaking is guided from the top level down to the lower, through a coordination of effects. The higher-level structure sets constraints, a kind of information, that guides the emergence of the higher order complexity. While the underlying systemic properties are the cause, the nature of the emergence is structured in specific ways from the top down.

In the language of dispositional essentialism, there is a generative process of causation flowing from dispositions and a selective process resulting from the underlying circumstances of the object or system and its history. In many cases, the top-level disposition creates or changes dispositions at the next level, in a cascade of causation operating downward across multiple levels. [v]

Considering alternative models of causation for emergent behaviors is helpful, but dispositions and histories do not complete the picture. Something gets the ball rolling, so to speak.

## Intentionality:

There is a critical difference between intentionality and agency. Intentions are behaviors that can be observed. Agency is a quality that must be inferred. Intentions may or may not be due to the actions of an autonomous, conscious agent.

When a white billiard ball strikes a red billiard ball, motion is transferred. This occurs as a result of the dispositions of billiard balls as massive, inelastic objects, their particular positions (history) in time and space, and the motion that had been previously

imparted to the first ball. That initial motion, including the relative speed and precise direction of the billiard ball, can be described as its intention. This does not presume that the billiard ball is a conscious agent. Yes, it caused the phenomenon as a consequence of its behavior, but its behavior was not conscious or independent. The motion and direction of the billiard ball was the consequence of prior causes. One possible prior cause was that someone chose to strike the white ball with a cue. In this case, the intention (motion and direction) of the billiard ball was imparted to it by the intention (a decision to impart motion and direction) of the conscious human agent.

In this example, both the billiard ball and the human have intention. We infer that the human, but not the billiard ball, was an agent. However, it is quite possible that the cue stroke of the human was accidental and not a conscious act. It is also possible that what we presumed to be a human was a robot. While we can observe the actions of the entity in striking the cue ball, we cannot observe his/her/its interior state. We can only infer that they acted consciously as an autonomous agent. Indeed, we can never prove the existence of other minds: Solipsism is a self-consistent, if unsatisfactory, philosophical position. But we can observe intention.

## Attraction:

Every break in the grand symmetries of the cosmos manifests intention. At each break, there is a change of state (movement) and a direction (selection process leading to an end state). This intentionality is an attraction for and movement to a stable pointer state ("attractor"). In the case of convergent evolution, we see specific multiple evolutionary lines developing common physiological features, such as eyes, wings or fins. As each line seeks to respond to similar environmental opportunities and challenges through mutation and selection, they are attracted to similar pointer state.

At the component level of a system, the individual units follow simple behavioral rules as they respond to the environmental pressures and constraints within the system. Their collective behavior drives the search process for end states that satisfy the systemic intention, those states to which the system is attracted. This process is oriented towards a goal, but the goal is aspirational, not prescriptive. Galaxies emerge in a cosmic gravitational dance - each unit of mass influencing the others as they collectively follow an elaborate pathway to stable galactic structures. The goal is not to create spiral or other specific shapes but to minimize local entropy. The system searches through available configurations, constrained by mathematical laws and prior history, attracted to one that achieves that goal.

## Cooperation:

At the system level, intention is attraction to a maximally efficient end state. At the component level, the behaviors that support the intention are cooperation and communication. The system and component levels require and facilitate the other. A solution that minimizes local entropy also minimizes average energy losses. Such

energy losses correspond to conflict, or friction, between individual components, and the minimization reflects compromise and cooperation.

The overall intention at every level of the cosmic evolutionary process is to support the emergence of higher level systems that minimize local entropy, and this requires that conflicts among system components be minimized. Each level sets the foundation for the next, in a sequential process that seeks increasing complexity and increasing local minimization of entropy. At each level, the component units respond with communication and cooperative behaviors responsive to the systemic intention. Stars dance with each other to create galaxies. Atoms embrace each other to create chemistry. Chemicals interact in incvressingly sophisticated ways to build living systems. Living systems evolve in complexity and functional capacities in colonies. Cells work collaboratively to support the healthy functioning of the entire organism of which they are a part. Self-reflective consciousness emerges, perhaps in the synchronous coordination of quantum behaviors within neuronal microtubules.[vi] Self-reflective conscious beings cooperate, and create institutions, to achieve mutually beneficial ends.

Among the cooperative behaviors of self-reflective conscious beings is the pursuit of science. Science is the intentional, collaborative exploration of the world. For many scientists, there is delight and joy in their individual process of discovery and collaboration. For the human race as a whole, science has conferred immense material benefits and mastery over the globe. At its best, science is a wonderful and intensely collaborative adaptation that serves to minimize discrepancy between theory and reality and maximize information - effectively exporting entropy to the larger world in the process.

## Reciprocity:

There is an additional feature to the cascade of emergent processes - they are reciprocally interactive. Reciprocity at the component level enables the system to seek adaptive solutions. Reciprocity between component and system levels is inherent in the dynamic of emergence --- components enable the system to search, and the system attraction to pointer states drives the selection. These relations flow up and down the emergent cascade. In the emergent history of our universe, everything is connected to everything else in a limitless web of reciprocity.

As human component units, we are each reciprocally connected to other humans through genetic and evolutionary heritage as well as through language and culture. As social creatures, we define ourselves and our lives through our relationships. We care, and are cared for. We love, and are loved. These reciprocal connections weave through time and space to every human now alive and every human that ever lived.

At the system level, we are the consequence of the complete history of prior emergent processes, a history of emergent threads weaving connections to all living things, to all times and places, and to the universe as a whole.

## Love:

Intention, attraction, cooperation and reciprocation are the definition of love. Cosmic intentionality is love flowing through the universe, guiding the emergent cascade. Each prior state evolves and moves towards a higher state, one reflecting a greater degree of intention, attraction, cooperation and reciprocation.

This emergent process has driven inexorably to self-reflective consciousness, a state where the component units are able to reflect on the universe and their role in it. The universe has given us life, beauty, joy and self-reflective consciousness - it has loved us. In turn, it is possible for each of us to reciprocate this love.

## Postlude:

As a grandfather, I have the joy of watching infants grow up. It is remarkable to watch them engage the world with great enthusiasm and fascination. My grandson will pick up a colorful block in his little hand and look at it intently. He will twist his hand and twirl his wrist to observe the block from different angles. Often, he will try to put it in his mouth – tasting and biting the block. He may throw it, sometimes shouting in glee as he glances back to make sure I see him, and then crawl after it to start the process over again. Each part of this spontaneous interaction with the block is an exploration, an effort to evaluate, assess and understand it, it's qualities and its uses. For him, the purpose of the block, and the world at large, is to be explored. The reward to him for that exploration is the delight and joy of discovery, as well as mastery. He loves the world --- and the world (including me) loves him back.

## Conclusion:

Let's revisit the choice we postulated at the beginning of this essay - do you believe the universe is an expression of randomness within mathematical forms, or do you believe there is a cosmic intentionality that provides generative guidance for the emergence of our universe in its specific and unique configuration? From an empirical standpoint, there is no answer. The question is undecidable. Yet the answer matters.

This essay provided evidence that cosmic intentionality is a reasonable, consistent and complete inference about why the universe is the way it is. We can see that emergent processes exhibit intention, that systems are attracted to particular states while component units behave collaboratively in selecting those states, and that the entire process across and within levels is reciprocal. These qualities define the operative cosmic principle as love. We have the opportunity to embrace and reciprocate this love, with gratitude, joy and delight, and to believe that we are a meaningful part of a grand purpose.

However, this inference is not a proof. Many will claim that it is equally plausible, if not more so, to infer that the quantum behavior at the core of reality is fundamentally random and that quantum superposition requires a multiverse. Perhaps this can form the basis for a reasonable, consistent and complete picture of reality. Yet, if the universe is random, and our world only one in the infinite multiverse, then what do our choices and decisions matter? Each choice point just triggers another split into alternate universes, indistinguishable from the rest. If intention and purpose are epiphenomenal, having no effect on the structure of the multiverse, then they do not matter. That's a rather depressing thought.

Choose as you will, but I believe the universe is meant to be lived in, to be explored, and to be loved. In return, the universe rewards us with life, with complexity, and with the capacity for knowledge, self-exploration and wisdom. And it loves us back. For this, I feel humble and grateful.

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End Notes:

[i] Andrei Linde, Vitaly Vanchurin. "How many universes are in the multiverse?" as reported in MIT Technology review, last downloaded 2-28-17. www.technologyreview.com/s/415747/physicists-calculate-number-of-universes-in-the-multiverse/

[ii] Max Tegmark, Our Mathematical Universe. Alfred A. Knopf, NY. (2014).

[iii] Anderson, P.W. (1972), "*More is Different: Broken Symmetry and the Nature of the Hierarchical Structure of Science*", Science 177 (4047): 393–396

[iv] George F. R. Ellis, *Recognising Top-Down Causation*, FQXi Essay Contest – Spring 2012

[v] Ian J. Thompson, Starting Science from God. Eagle Pearl Press, Pleasanton CA. (2011) p.76

[vi] *Consciousness in the universe: A review of the 'Orch OR' theory*, by Stuart Hameroff and Roger Penrose, Physics of Life Reviews Volume 11, Issue 1, March 2014, Pages 39–78.

Additional References:


Capra, Fritjof and Luisi, Pierre Luigi. The Systems View of Life. Cambridge University Press. Cambridge UK (2014)

Eck, Allison *How Do You Say "Life" in Physics?* Nautilus. March 17, 2016.

England, J.L. *Dissipative adaptation in driven self-assembly*. Nature Nanotechnology 10, 919-923 (2015).

Gleiser, Marcelo. A Tear at the Edge of Creation. Dartmouth College Press. Lebanon NH. (2010)

Greene, Brian. The Fabric of the Cosmos. Vintage Books, NY (2004)

Mitchell, Melanie. Complexity: A Guided Tour. Oxford University Press, Oxford UK. (2009)

Penrose, Roger. Cycles of Time. Vintage Books. NY. (2012)

Smolin, Lee. The Trouble With Physics. Mariner Books, NY (2006)