

The Grammar of Life Itself

How Humberto Maturana's Autopoiesis Became the Biological Foundation of the Closure Framework

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To live is to know. Living as a process is a process of cognition. This statement is valid for all organisms, with or without a nervous system.

Humberto Maturana and Francisco Varela, *Autopoiesis and Cognition*, 1980

Every finite closure generates remainder. The remainder is not noise. It is the proof that the grammar is finite.

CF Dietz, *Consciousness, Closure, and the Cosmos*, 2026

Abstract

Humberto Maturana spent six decades arguing that living systems are not machines that process inputs and produce outputs but self-producing networks that maintain their own organization through continuous regeneration of their components. His concept of autopoiesis, developed with Francisco Varela, defines life as organizational closure: a network of processes that produces the very components that constitute it. His account of structural coupling describes how autopoietic systems interact with their environments without losing their organizational identity. His claim that cognition is coextensive with life, that to live is already to know, dissolves the boundary between biology and epistemology that Western thought has maintained for centuries. This paper argues that Maturana's autopoiesis is the biological foundation of the closure framework developed in *Consciousness, Closure, and the Cosmos*, and that the closure framework in turn provides the philosophical completion that Maturana's biology has been reaching toward without fully arriving at. Autopoiesis is organizational closure: a living system is a closure regime that produces its own boundary conditions. Structural coupling is the interaction between closure regimes at their boundaries, mediated by remainder. Cognition as life is closure maintaining its own identity criteria in the face of what the world presents. And Maturana's biology of love, his account of how love is the biological foundation of human sociality and ethics, is the closure framework's account of what happens when cognitive closure reaches toward what exceeds it. Maturana arrived at the origin of the lineage that runs through Noble, Friston, and Lawson to the CC-C framework. This paper honors that arrival.

1. The Frog's Eye and What It Did Not Report

In 1959, a young Chilean biologist named Humberto Maturana published a paper with Warren McCulloch, Walter Pitts, and Jerome Lettvin that would eventually change the way science thinks about perception, cognition, and life itself. The paper was titled *What the Frog's Eye Tells the Frog's Brain*. Its findings were unexpected and their implications took decades to absorb.

The expectation before the experiment was that the frog's visual system would function like a camera: faithfully transmitting to the brain a representation of whatever was in the visual field. The retina would encode the light, the optic nerve would carry the signal, and the brain would construct an image from the data. The frog's eye would tell the frog's brain what was there.

What Maturana and his colleagues found was entirely different. The frog's retina did not transmit a general representation of the visual field. It responded selectively to specific patterns: moving edges, small dark objects against lighter backgrounds, sudden changes in illumination. What the frog's eye told the frog's brain was not a description of the world. It was a set of responses relevant to the frog's survival: food is here, danger is near, light has changed. The visual system was not reporting reality. It was constituting a world of significance for the frog.

Maturana spent the next six decades drawing out the implications of that finding. If the visual system does not report a pre-given reality but constitutes a world of relevance for the living organism, then perception is not a passive reception of external data but an active organization of the organism's relationship to its environment. And if that is true of visual perception, it is true of all cognition. And if it is true of all cognition, then cognition is not a special capacity of organisms with brains. It is what any living system does in maintaining its organization against the constant pressure of an environment that could dissolve it. Cognition is not a feature of life. It is what life is.

That conclusion, radical when Maturana first proposed it and still not fully absorbed by mainstream biology, is the starting point of this paper. What kind of thing is a living system, such that cognition is constitutive of it rather than merely a capacity some living things possess? The answer Maturana developed, through autopoiesis and structural coupling, is the answer the closure framework independently derived. The two accounts are the same account stated in different vocabularies, arrived at from different directions across half a century of separate work.

2. Maturana's Four Claims

Maturana's contribution to biology and philosophy of mind has four interconnected components, developed across his work with Francisco Varela and in his later solo work on the biology of love and cognition. Each is worth stating clearly before the closure framework engages it.

2.1 Autopoiesis: Life as Self-Production

The word autopoiesis was coined by Maturana around 1970 from the Greek roots for self and production. An autopoietic system is one that continuously produces the very components that constitute it. A living cell is the paradigm case: the metabolic network of the cell produces the

proteins, lipids, and other molecules that make up the cell's structure, which in turn constitutes and maintains the metabolic network that produces them. The cell is a network of processes that produces itself.

This is not a circular description but a precise characterization of what distinguishes living systems from all other physical systems. A machine can maintain its organization, but it does so by processing inputs provided from outside. A living system produces its own inputs, maintains its own boundaries, and regenerates its own components through the very processes that those components enable. The organization is closed: not closed in the sense of having no exchange with the environment, but closed in the sense that the processes that maintain the organization are internal to the system and refer only to themselves.

Maturana was careful to distinguish the organization of a living system from its structure. The organization, the autopoietic closure, is what makes the system the kind of system it is: a living cell rather than a chemical reaction, a cognitive system rather than a mechanism. The structure, the specific molecules and their spatial arrangements, can change continuously while the organization remains the same. A cell that has replaced all its molecular components is still the same cell if its autopoietic organization has been continuously maintained. Life must change to stay the same.

2.2 Structural Coupling: How Living Systems Meet the World

An autopoietic system is organizationally closed but structurally open. Its organization, the network of processes that produces itself, is maintained without reference to the environment. But its structure, the specific physical components and their arrangement, is continuously shaped by interactions with the medium in which it exists. Maturana calls this structural coupling: the ongoing mutual modification of structure between an autopoietic system and its environment, constrained by but not determined by either side.

Structural coupling is not instruction. The environment does not tell the living system what to do. It provides perturbations that trigger structural changes in the system, but the specific structural changes that occur are determined entirely by the system's own organization, not by the perturbation. A bacterium swimming toward a glucose gradient is not being instructed by the glucose to swim toward it. The glucose provides a perturbation. The bacterium's autopoietic organization determines the response. The world triggers. The organism decides, in the precise sense that the organism's organization specifies the range of possible responses to any perturbation.

This means that the environment of a living system is not an objective pre-given reality to which the system must adapt. It is a niche: the domain of interactions that the system's organization permits. Two organisms with different organizations inhabit different niches even if they occupy the same physical location. The world each organism has is the world its organization constitutes through structural coupling. There is no view from nowhere. Every living system has a world, and that world is constituted by what its organization makes relevant.

2.3 Cognition as Life: To Live Is to Know

Maturana's most radical claim is that cognition is not a special capacity of organisms with nervous systems. It is the fundamental property of all living systems. To live is to maintain autopoietic organization in the face of environmental perturbation. That maintenance requires the system to distinguish perturbations that are relevant to its continued organization from those that are not, to respond to the former in ways consistent with its own structural dynamics, and to maintain its identity through structural change. That is cognition: effective action in the maintenance of life.

A bacterium that navigates a glucose gradient is cognizing: it is effectively distinguishing relevant from irrelevant perturbations and responding in ways that maintain its autopoiesis. A bacterium that fails to cognize dies. The same is true at every level of biological organization. The immune system cognizes when it distinguishes self from non-self. The organism as a whole cognizes when it maintains its structural integrity in a changing environment. Cognition, in Maturana's sense, is not thinking. It is the effective maintenance of organizational identity in the face of what the world presents. And since that is what living is, cognition and life are coextensive.

This account dissolves the hard boundary between biology and epistemology that Western thought has maintained since Descartes. Knowledge is not a representation of an external reality in an internal mind. It is the effective operation of a living system in its medium. What an organism knows is not a picture of the world. It is a set of effective distinctions and responses that allow it to maintain its organization in the world it inhabits. Knowing is not about truth. It is about fit.

2.4 The Biology of Love: Cognition Extended to Ethics

In his later work, particularly *The Origin of Humanness in the Biology of Love* co-authored with Ximena Verden-Zoller, Maturana extended his account of autopoiesis and structural coupling into the domain of human sociality and ethics. His central claim is that love is not a sentiment added to biological life but the fundamental biological condition of human social existence. Love, in Maturana's sense, is the acceptance of the other as a legitimate other in the domain of coexistence. It is what allows structural coupling between human beings to constitute shared worlds rather than competitive interactions for dominance.

This claim follows from the logic of autopoiesis. If cognition is the effective maintenance of organizational identity through structural coupling with the environment, and if the most significant environmental features for a social organism are other members of its species, then the quality of structural coupling between organisms determines the quality of the shared world they constitute together. Love, as acceptance of the other, is the structural coupling that produces shared worlds rather than worlds of threat and defense. Ethics is not imposed from outside biology. It is what biology requires when autopoietic systems are embedded in social niches that include each other.

3. What Maturana Needs

Maturana's biology is the most radical and comprehensive account of life and cognition produced in the twentieth century. It dissolves the mind-body problem by showing that cognition

is biological. It dissolves the subject-object problem by showing that every organism constitutes its own world through structural coupling. It provides a foundation for ethics in the biology of love rather than in abstract moral reasoning. These are extraordinary achievements.

There is, however, a question Maturana's framework raises with particular sharpness without fully answering it. If every living system constitutes its own world through structural coupling, and if there is no view from nowhere, then what is the status of the world that exceeds any organism's constitutive capacity? Maturana acknowledges that there is something out there, a medium in which autopoietic systems exist and with which they are structurally coupled. But his framework does not provide a positive account of what that medium is, beyond noting that it provides perturbations that trigger structural change.

The closure framework's account of M, the inexhaustible ground that every closure opens onto without exhausting, provides exactly this positive account. M is not the sum of all organisms' niches. It is the ground from which every niche is constituted, and which exceeds every niche structurally. The medium that Maturana acknowledges as the occasion for structural coupling is M: genuinely there, with real structure, generating genuine perturbations, but never fully capturable by any autopoietic system's organization. Maturana points at M without naming it. The closure framework names what he was pointing at.

Additionally, Maturana's account of cognition, while comprehensive as a biological account, does not engage the question of conscious presence: what it is like to be a living system that cognizes. His framework describes the functional and structural properties of living cognition without addressing whether there is felt experience associated with it, and if so what its relationship to autopoietic organization is. The closure framework's distinction between C, bare conscious presence, and c, consciousness with content, addresses this gap directly. Autopoiesis explains the c side of experience: how content is constituted through organizational closure and structural coupling. It leaves C, the felt interior of being a living system, unexplained. The closure framework treats C as a primitive that autopoiesis does not derive but that autopoiesis depends upon.

4. Two Concepts That Complete What Maturana Began

The closure framework is introduced here at the minimum level needed to show how it grounds and completes Maturana's account. Two concepts only. Readers who want the full architecture are directed to Consciousness, Closure, and the Cosmos.

4.1 Closure Regime: What Autopoiesis Is Philosophically

A closure regime, in the CC-C framework, is a system that stabilizes some content by drawing distinctions, establishing identity criteria, and maintaining lawful relationships among its elements. It constitutes facts within its scope and generates remainder at its boundary: the content that the closure's identity criteria cannot model.

Autopoiesis is organizational closure in precisely this sense. The autopoietic network of a living cell draws distinctions between what is inside and what is outside, between what is part of the network and what is environment, between what is a relevant perturbation and what is not. It maintains identity criteria: the criteria that make this particular cell this cell rather than a different

one or no cell at all. And it generates remainder at its boundary: the features of the medium that the cell's organization cannot model, cannot respond to in ways consistent with its continuation, and which therefore accumulate as the structural source of evolutionary pressure.

The closure framework adds to Maturana's account the formal concept of remainder, which is implicit throughout his work but never named as such. When Maturana describes how living systems encounter perturbations that their organization cannot accommodate and either respond by structural change or die, he is describing the experience of remainder accumulating beyond the threshold that the current organizational closure can absorb. Remainder is the formal name for what drives structural coupling to produce new structural configurations: the mismatch between the closure's current organization and what the world presents.

4.2 Nested Closure and M: What Structural Coupling Opens Onto

Maturana's account of structural coupling describes how autopoietic systems interact with their environments without losing their organizational identity. The closure framework clarifies what this interaction is at the structural level: the closure boundary of one autopoietic system is the site at which the remainder of that system meets the remainder-generating capacity of what lies outside it. Structural coupling is the ongoing negotiation at the closure boundary between what the system can model and what the world presents that exceeds that modeling.

The nested structure of living systems, cells within organisms within ecosystems, is the nested closure hierarchy the CC-C framework describes. Each level is a genuine closure regime with its own organization and remainder. Each level's remainder is the occasion for the structural coupling that generates higher-level closures. The organism as a closure regime sets the boundary conditions within which its cellular closure regimes operate. The ecosystem as a closure regime sets the boundary conditions within which organismic closure regimes operate. This is Noble's biological relativity and Friston's nested Markov blankets both, derived here from Maturana's original account of autopoietic organization.

And what the closure boundary opens onto, what structural coupling puts the living system in contact with at every level, is M: the inexhaustible ground that Maturana acknowledged as the medium without being able to characterize it positively. M is not passive. It generates genuine perturbations. It resists closures that are not adequate to its structure. It is the source of the remainder that drives structural change, evolutionary novelty, and the expansion of cognitive niches across biological time. Maturana described the encounter with M without naming it. The closure framework names what the frog's eye was already opening onto in 1959.

5. Four Claims, One Structure

The vocabulary correspondence between Maturana's biology and the closure framework is direct and precise. What Maturana calls autopoiesis, the self-producing organizational closure of living systems, the closure framework calls a closure regime. What Maturana calls the organization of a living system, the identity criteria that persist through structural change, the framework calls the closure's constitutive distinctions and lawful relationships. What Maturana calls a perturbation that the system's organization cannot accommodate, the framework calls remainder. What

Maturana calls structural coupling, the ongoing interaction between organism and medium at the boundary of the organism's organization, the framework calls the encounter of a closure regime with what it opens onto. And what Maturana acknowledges as the medium, the something that is out there providing perturbations without being fully capturable by any organism's niche, the framework calls M.

5.1 Autopoiesis Is Organizational Closure

Maturana's definition of autopoiesis as a network of processes that produces the very components that constitute it is a definition of organizational closure. The network is closed in the relevant sense: its constitutive processes refer only to each other and to the organization they collectively maintain. No process in the network requires reference to anything outside the network for its specification. The closure is the organization.

The closure framework adds the concept of remainder to this account. An autopoietic system is organizationally closed but it generates remainder at its structural boundary: features of the medium that its organization cannot model or respond to while maintaining its current organization. That remainder is not a failure of the autopoietic closure. It is its structural consequence: a finite organizational closure will always encounter aspects of the world that exceed its modeling capacity. The remainder is what drives structural change. Without remainder, an autopoietic system would be in perfect equilibrium with its environment and nothing would change. Remainder is the engine of life as well as its structural horizon.

5.2 Structural Coupling Is Remainder Meeting Remainder

Maturana's structural coupling describes how two autopoietic systems, or an autopoietic system and its abiotic environment, undergo reciprocal structural modification while each maintains its own organizational closure. Neither system controls the other. Each triggers structural change in the other through the perturbations it generates. The coupling is ongoing and reciprocal and produces a history of co-modification that Maturana calls a history of congruent structural change.

The closure framework clarifies the mechanism of structural coupling at the level of first principles. Two closure regimes in structural coupling are meeting at their respective boundaries. At those boundaries, each regime generates remainder: the features of the other that its own organization cannot fully model. That remainder is the perturbation that triggers structural change. Structural coupling is not two closed systems exchanging signals. It is two closure regimes encountering each other's remainder and responding in ways consistent with their own organizational identity. The coupling is real, the modification is real, and the history it produces is a record of how each regime's closure has been shaped by the remainder generated at the boundary of the other.

5.3 Cognition as Life Is Closure Maintaining Itself

Maturana's equation of cognition with life, his claim that effective action in the maintenance of autopoiesis just is cognition, maps precisely onto the closure framework's account of what any closure regime does to maintain its identity across time. A closure regime maintains

itself by constituting facts within its scope, managing remainder at its boundary, and undergoing structural change when remainder accumulates beyond the threshold its current organization can absorb. That continuous maintenance is cognition in Maturana's sense: effective action in the preservation of organizational identity.

The closure framework extends Maturana's account by specifying what happens when remainder accumulates beyond the current closure's capacity. Supersession: the closure updates its identity criteria, its constitutive distinctions, its lawful relationships, in ways that reduce the mismatch between its organization and what the world presents. Maturana describes this as structural change that maintains autopoiesis while modifying structure. The closure framework names the mechanism: supersession driven by accumulated remainder. The living system does not experience its own supersession as updating a model. It experiences it, where it experiences anything at all, as the ongoing challenge of remaining alive in a world that constantly presents what the current organization was not prepared for.

5.4 The Biology of Love Is Closure Reaching Toward M

Maturana's biology of love is his most humanly important claim and the one that most directly engages the territory the CC-C framework occupies beyond biology. His argument is that love, understood as the acceptance of the other as a legitimate other in the domain of coexistence, is the biological foundation of human social life rather than a sentiment added to an underlying competitive biology. We became human, Maturana argues, through a evolutionary history in which structural coupling between individuals was characterized by mutual acceptance rather than dominance: by love rather than aggression. That history constituted the cognitive niche of humanness: the shared world of language, emotion, and social coordination that distinguishes human life from other primate life.

In closure framework terms, the biology of love describes what happens when two cognitive closure regimes, two human beings, engage in structural coupling characterized by genuine openness to each other's remainder rather than defensive protection of their own closure against perturbation. Love is the willingness to let the other's remainder reach you, to allow what the other presents that your current organization cannot fully model to trigger genuine structural change rather than defensive rejection. It is the most demanding form of structural coupling, and Maturana is right that it is biological: it requires organisms organized in specific ways, with specific histories of structural coupling, to be capable of it. But it also points beyond biology, toward the M that every closure opens onto and that love, more than any other human activity, makes contact with.

6. What the Encounter Produces

The encounter between Maturana's autopoiesis and the closure framework has consequences for both.

For Maturana's framework, the closure account provides the formal vocabulary that makes its deepest claims more precisely statable. Autopoiesis is organizational closure. Structural coupling is remainder meeting remainder at closure boundaries. Cognition is closure maintaining

identity through supersession. The medium is M. These formulations do not change what Maturana argued. They give his arguments a precision that makes them more accessible to philosophers who need explicit concepts, more engaging to mathematicians like Friston who need formal structures, and more defensible to biologists like Noble who need the claims to connect to observable mechanisms. The closure framework is the philosophical expression of what Maturana's biology was always implying.

For the closure framework, Maturana's work provides the biological grounding it needs at the cellular level: the level below the organismic cognition that the Grammar of Healing demonstrates and the level at which the physics and chemistry of life meet the organizational principles that make life life. The closure framework claims that nested closure hierarchies are structurally necessary for any organized system. Maturana's autopoiesis is the empirical demonstration of exactly that claim at the level of living cells. Every cell that has ever existed is a closure regime maintaining its organizational identity through structural coupling with its medium. The three billion years of cellular life on earth is the oldest and most comprehensive confirmation available of what the closure framework claims about organized systems.

For biology and philosophy jointly, the encounter between Maturana and the closure framework completes a lineage. Maturana showed that living systems are self-producing organizational closures. Noble showed that biological organization operates at multiple levels simultaneously with genuine downward causation between them. Friston showed that the mathematics of prediction error minimization describes the behavior of any system with a Markov blanket. Lawson showed that all human knowledge is constituted through closure over an open world. The CC-C closure framework is the philosophical account that names what all four were describing: nested closure regimes generating remainder, using that remainder, and opening onto the inexhaustible ground that no finite closure exhausts.

Maturana did not name it M. He called it the medium, the environment, the something that is out there. He spent sixty years characterizing what living systems do in relation to it without characterizing what it is in itself. That restraint was scientifically appropriate: biology studies what organisms do, not what the ultimate ground of their doing is. The closure framework steps where biology rightly hesitates, and names the ground: M, the inexhaustible source from which every closure constitutes its world and to which every remainder points back.

7. The Grammar of Life Itself

A frog's eye in 1959 told a young biologist that the world is not reported to living systems. It is constituted by them. That observation, simple in its statement and radical in its implications, opened six decades of work that transformed our understanding of what life is, what cognition is, and what it means to be a living being in a world that exceeds every description of it.

Maturana was right. Autopoiesis defines life. Structural coupling defines how living systems meet their worlds without losing themselves. Cognition is coextensive with life, not a capacity added to it but the very activity of maintaining organizational identity in the face of what the world presents. And love is biological: the form of structural coupling that produces shared worlds rather than worlds of competition, and the foundation of everything distinctively human.

What he was pointing at throughout, the medium that perturbation comes from, the something that is out there generating structural challenges that no organism fully models, the ground that exceeds every organizational closure while constraining none of them to be what they are, has a name in the closure framework. M. The inexhaustible ground that every autopoietic closure opens onto and none exhausts. The source of the remainder that drives structural change across evolutionary time. The ground that love, more than any other biological activity, makes genuine contact with.

The grammar of life itself is what Maturana spent sixty years reading in frogs and cells and nervous systems and human social worlds. The closure framework names what he was reading: the structural necessity of finite organized systems opening onto what exceeds them, generating remainder at the boundary, and using that remainder as the engine of everything that living beings do. Autopoiesis is where the lineage begins. Everything that follows, in Noble's biology, in Friston's mathematics, in Lawson's philosophy, in the CC-C framework, is a continuation of what the frog's eye first revealed.

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Author's Note

*This paper is the fourth in a series engaging thinkers whose work converges with the closure framework developed in *Consciousness, Closure, and the Cosmos*. Humberto Maturana (1928-2021) passed away before this paper was written. His intellectual presence in the living conversations of systems biology, cognitive science, philosophy of mind, and family therapy was sustained and active throughout the twenty-first century, and the convergence between his work and the CC-C framework was identified during a period when his ideas were being actively extended by researchers, clinicians, and philosophers around the world. The series honors him as the founder of the lineage: the biologist who first saw, in the frog's eye, that living systems constitute their worlds rather than report them, and who spent sixty years working out what that seeing implies. The series owes him more than any other single thinker, because autopoiesis is where the understanding that the CC-C framework formalizes first became visible in a living cell.*