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Context Changes Everything

How Constraints Create Coherence

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An Abundance of Constraints

Coherence-making by constraints is one thing. Coherence maintenance and persistence is another. As implemented by default governing constraints, maintenance and persistence presuppose relatively steady background conditions. For example, regular solar flares and neutron star collisions light years away do not threaten the planet's atmospheric dynamics, whose governing constraints are metastable to such routine fluctuations. Earth "treats" those slower cycling rates as "constants" (Allen and Starr 1982; Salthe 1985, 2001).

But conditions inevitably change, and existing governing constraints that keep local systems in balance can become precarious, unable to maintain coherence. Interlocking constraints that realize metastability will decohere when either context-independent or existing constitutive constraints are sufficiently perturbed. Interdependencies that were once stable and effective become threatened. Eventually, all coherence is threatened by the second law and the inexorable march of time; unusually rapid and severe changes can render its governing constraints ineffective and even unresponsive to changing conditions. Any responses the system does manage to produce will likely be too slow, stale, and sluggish—mismatched to current conditions. Resulting decompensation is as true for human organizations as for natural ecosystems (Woods 2016, 2018).

Warning signs of impending disintegration appear. In natural and simulated systems alike, unusually large fluctuations and rapid oscillations presage an approaching instability. Trends in the earth's climate offer stark evidence of the threat today: extreme wildfires and record temperatures and rainfall are indicative of the planet's stressed governing constraints. Ecosystems become saturated and depleted. When existing governing constraints are no longer sufficiently coherent (or sufficiently adequate to current conditions) to preserve their interdependencies, organisms, ecosystems, and cultures alike cannot cope. The possibility of disintegration looms. Stars burn out. In living things, senescence sets in.

Changes in constraints at scales closer to those of the threatened system can directly alter its chances of survival. Supplementary constraints tacked on to default enabling and constitutive/governing constraints can reinforce existing organization and thereby support the system's persistence. They prolong its metastability in the face of strong instabilities.

Adding extra oomph to existing constraints of all stripes keeps gradients from equilibrating and interlocking interdependencies from decohering. Add-on support like new varieties of memory and regulatory constraints can keep systems sufficiently stable and prolong their existence. Others constraints like "more-making" (Eldredge 2015), buffers, and isolation can also keep systems from thermalizing by holding conditions away from equilibrium. Density, motility, and migration (Agosta and Brooks 2020) are yet other constraints that access new energy gradients with fresh resources. Some of these add-on constraints appeared only with the origin of life; others existed much earlier. Some are context independent; others are context dependent. This chapter presents a cursory survey of common add-on constraints that prolong persistence.

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Repetition, replication, regularity, redundancy, and reproduction—"more-making" (Eldredge 2015)—are examples of such constraints.

The common prefix is not coincidental. Serving as context-independent constraints, various forms of again, again, and again increase the numbers of those entities or processes in the state space. By increasing their percentage in the overall population, the resulting density deforms the state space and takes systems even further from equilibrium with the environment. More, more, more increases the likelihood that those systems will not quickly dissipate in the face of perturbations and fluctuations. It also increases the likelihood that their traits do not quickly degrade.

Repetition

As a case in point, short nucleotide sequences often repeat in the genome. The gene for the flower of Gregor Mendel's peas has two repeats in its pigmentation gene: each repeat codes for only one of the flowers' two colors, white or purple. When the number of repeats varies, each repeat can represent an inherited allele. This reinforces the faithful persistence of that pure line trait. Repetition was also among the earliest human communications techniques to improve fidelity of transmission in a noisy medium. Native American smoke signals and the talking drums of the Yoruba people are long-distance communication codes that date back to antiquity. By coming at evenly spaced intervals, regular (hence improbable) angular rotations of pulsars, for example, reveal the presence of two constraints, magnetic field and local density of matter. Lighthouse makers like the family of author Robert Louis Stevenson likewise understood that regular flashes of light convey information because they are regular. Repetition and regularity on their own do not impart energy; like timing, they preserve and transmit information by deviating from equiprobability and randomness. As constraints, they convey information of constraints.

In human organizations, too, regular reenactment of constrained behavior preserves social cohesion and adherence to religious and cultural teachings. Yearly rituals and their attendant prescriptions and proscriptions keep cultures and religions alive by reinforcing existing constraints. Personal habits and routines also reinforce constraints. We misplace keys less often by leaving them on the same console. Practice might not make perfect, but it tends to consolidate it by preserving constitutive constraints in nonequilibrium.

Mechanical engineers rely on a related mechanism,[1] *redundancy,* to improve system reliability. By adding extra components that can compensate for any loss or damage to the main one, redundancy aims to secure *fail-safe* conditions and keep the system from disintegrating. If one signal does not get through or a component fails, another takes over. In both information theory and engineering, then, more, more, more increases the likelihood that message transmission and functionality do not degrade. Redundant measures are, therefore, context-independent constraints that keep systems away from equilibrium, despite perturbations. They shield coherence and functionality from equilibration. Redundancy is expensive, however, with diminishing returns. If the first signal gets through or the primary component works as intended, redundant units are superfluous and energetically costly.

Replication

Replication, making a copy of something, is a variety of repetition; it is another form of more making, a context-independent constraint. Unlike redundancy, replication does not just add an extra existing copy; it makes new copies. *Mitosis*, for example, produces two identical daughter cells. By doubling the number of tokens at each turn, mitosis takes conditions even further from equilibrium.

Mitosis is not a random cut through a cell, like breaking up terrazzo flooring. As a form of asexual reproduction, mitosis qualifies as more-making because it duplicates an already coherent set of interdependencies.

Daughter cells of mitosis are more of an already organized coherent whole, the parent cell. Mitosis, that is, replicates the constraint regime of a particular type of entity, an organized cell. In transmitting bound type-level information from parent to an increasing number of daughters in subsequent generations, mitosis extends the reach of a distinct coherent constraint regime, a type. By duplicating an already coherent dynamic, mitosis prolongs an interactional type of entity into future generations.[2]

Cloning also makes another full organism like the original. Like mitosis, cloning replicates bound information by making more, more, more of the long-range correlations and constraint regimes that give coherence to a type. However, cloned animals like Dolly, the sheep, are born with the biological age of the stem cell from which they were cloned. Clones, in other words, replicate not only the parent's type identity; they also replicate at least some of the cloned organism's individuated characteristics. They carry the experiential record of the cloned organism's context-dependent constraints into a new embodiment. They transmit not only the inherited constraint regime but its epigenetic one. Clones are nevertheless replicates because, in addition to inherited constraints acting as constants, they embody a memory or record of the earlier ontogenetic path in their cloned structure and dynamics. Their very being embodies and extends a coherent trajectory. Replicating a differentiated cell type as well as an individuated token are characteristic of path-dependent processes operating simultaneously on different time scales.[3]

As instances of context-independent constraints, repetition, regularity, redundancy, and replication produce more tokens of the same type. None, however, directly increases type diversity or variety.[4] As noted in chapter 4, innumerable identical tokens of one type of entity are no variety at all. As obsessive-compulsive disorders demonstrate, diversity is not a cardinal measure. Cut off from contextual constraints that would ground them as meaningful, timely, and appropriate, repetitive habits and practices decoupled from context become compulsions.

This all changes with horizontal gene transfer (the lateral movement of genetic material between organisms, other than between an organism and its offspring) and the gene shuffling of sexual reproduction; these introduce novel context-dependent constraints that generate emergent interdependencies with an expanded possibility space. This new variety of context-dependent constraints does not replace earlier forms of more-making; it gets added on to them. Even *transposons*, sequences of DNA that jump from one site in the genome to another, jump to specific sites. They are context-dependent, not random.

Reproduction

Sexually reproducing organisms produce gametes (sperm and egg cells) through *meiosis*. Unlike daughter cells produced by mitosis, each of which carries the full information of the original, meiotic sequences yield four cells (sperms and eggs), each with half the chromosomes of one parent. These do not directly duplicate the full coherent organization of the original parent. Biologically, then, haploid germ cells are not replicates. Two haploid germ cells must combine to form an organism with the full complement of genes. Significantly, not only does the shuffling preserve the species' lineage, but individuals born of sexual reproduction also realize a novel combination of traits. New variants are produced, not by random mutations but directly by the multiply realizable constraints of gene shuffling; combined with the expanded possibility space afforded by horizontal gene transfer between bacteria, and between unicellular eukaryotes, a wider range of traits and behavior that nevertheless remains true to type opens up.

At the phenotype level, that is, sexual reproduction and horizontal gene transfer introduce new context-dependent constraints that can generate novel interactional types whose viability and life span are wider in scope and reach. These support the multigenerational constraint regimes we call lineages. They persist longer than their individual tokens. Constraints on both scales work in tandem. As a result, a population of sexually reproducing organisms has a more extended adaptive space in which to modify and survive (Kirschner and Gerhart 2005; Woods 2018). Subject to the limits of the possibility space set by the lineage's type, sexual reproduction increases flexibility and viability.

Phrased otherwise: gene shuffling, the preeminent context-dependent enabling constraint of sexual reproduction, does not make more of each parent, as mitosis does. By creating truly novel combinations (novel token interdependencies), gene shuffling breaks through the message variety trap of context-independent constraints. By endogenously producing novel variants, sexual reproduction creates a coordination pattern with a larger possibility space. Combined with horizontal gene transfer, these constraints enable the formation of multiply realizable diachronic interactional types we call biological lineages; these conserve unity of type while simultaneously allowing increasingly diverse tokens.

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Epigenetic modifications and the gut microbiome's metagenome are further add-on enabling constraints that extend metastable coordination dynamics: symbiosis, mutualism, commensalism, and parasitism are variations of context dependence and coherence making. Epigenetics and the gut microbiome do not replace mitosis in individual organisms any more than sexual reproduction did; indeed, it can be difficult to determine which came first. The immunoprotection that the microbiome in the mother's birth canal confers on vaginally birthed infants is yet another example of interlocking context-dependent constraints enabled by feedback loops at more than one spatiotemporal scale (mother's and child's lifespans). Spatial contextual constraints change the state space's topology; they expand the coherent dynamics of interlocking constraints, extend constraint space, and allow its future exploration by actual organisms.

By increasing type diversity, reconfigured constraint regimes enhance their flexibility and, in consequence, their evolvability. Contextually constrained types, it will be recalled, are multiply realizable. Even today, some sexually reproducing species retain the potential to replicate asexually under certain conditions such as drought. Ordinary, temporally constrained transformations such as those from tadpole to frog, and from larvae to pupae to butterfly, are considered a single constraint regime that activates or inhibits processes in response to contextual cues. But these abrupt phase changes can also be considered distinct constraint regimes that alternate depending on cued contexts as much as different tokens of a persisting constraint regime.

The organism's genome recodes bound information as instructions for processes at multiple scales. As described earlier, instructions are sets of spatiotemporally coded constraints that realize and maintain tokens of a type. No phenotype displays the full range of its lineage's bound information; actual living things realize only a context-dependent subset of the lineage's more encompassing type-defining coherence (what Brooks and Wiley 1988 call H_{max}). Governing constraints modularized in an organism's genome preserve the species' type by controlling gene expression such that phenotypes remain within the boundaries of that constraint framework. Regulatory genes governing developmental processes are specialized to that function and cued to actual contextual features to which they were evolutionarily entrained and to which they differentially respond. By simultaneously satisfying a number of constraints, however, regulatory genes can transmit and conserve bound information that describes a circumscribed possibility space.

By increasingly relying on the enabling powers of context-dependent constraints such as gene shuffling, horizontal gene transfer, epistasis, and epigenetics (rather than on faithful more-making alone), the dynamic of coherence-making itself evolves. *Epistasis* makes the effect of a given mutation depend on the presence or absence of other genes and earlier mutations; epigenetics integrates environmental and behavioral influences without genetic mutations. Over evolutionary time, coherence making appears to increasingly incorporate context-dependent constraints like epistasis and epigenetics. As a result of these context-dependent constraints acting together, evolvability and natural selection are facilitated. It seems evident that by facilitating novel forms of interaction, this process of complexification accelerates and is likely responsible for the emergence of consciousness, symbolic thought and language, culture, industrialization, globalization, and other traits of the Anthropocene.

Unity of Type in Species, Demes, and Memes

"Species are strictly genealogical, evolutionary units." By way of contrast to "economic units," Eldredge's term for processes that transfer energy, species can be considered more-makers only if their historical constraints are effective, if they reproduce "heritable information ensconced in the germ line genome" (Eldredge 2015, 304–305). In the terminology used here, species realize a lineage's constraint regime by embodying and enacting heritable context-independent information modularized both in the germ line and in epigenetically and epistatically sedimented constraints regulating gene expression. Once again, the information that persists in each case is enacted as unity of type (Brooks 2010), a distinct second-order constraint regime that becomes increasingly generic and flexible over evolutionary time.

Such constrained interdependencies can also be transmitted and preserved across generations of social organization. *Memes* are constraints that establish boundaries, coordinates, and attractors in mental and social space. We can understand their dynamics better by thinking of them as socially transmitted constraints that frame and bias (weight) cognitive possibility spaces and their constraint architecture. They enable the reproduction and enactment of easily transmissible information about mental and social properties and parameters. The placement and traits of the mental and social attractors, including their ruggedness, change in response to the spread of memes.

Constraints enable memes and *demes*, subdivisions of populations that typically breed among themselves, to form and persist. No doubt geography served as the main enabling and restrictive constraint in the generation and conservation of demes, be they human, plant, or animal demes. Each set of coherent interdependencies that identifies a species, deme, or meme reflects a constraint regime turned context-independent module of conserved interdependencies. Such interlocking interdependencies are not monolithic and blocklike. By quickly adapting to each local culture, memes can shape-shift to individuate lineages, cultures, and mindsets. But by highlighting just one or two features, one cartoon or pithy comment can capture and easily convey the complexity of those interdependencies. "That's a Spartan lifestyle!"

Gatlin (1972) identified the key to vertebrate evolution as keeping basic constraints fixed while simultaneously allowing the influence of context-dependent constraints to expand dramatically. This theme and variation pattern seems to represent a general motif: enabling constraints precipitate a phase transition to a new possibility space, a constraint regime which itself becomes a new inhomogeneity that taps new gradients. Sexual reproduction, lineages, demes, and even memes are evolutionarily recent coherent dynamics that increasingly rely on context dependence to precipitate ever more extended and long-lasting interdependencies, with ever more complex tokens, in every more complex constraint spaces. Because all complex systems are constrained in path-dependent trajectories at multiple temporal scales, organisms become increasingly specified and individuated during their individual lifetimes. Epigenetics demonstrates that these modified and individuated traits can feed back into the dynamic and continue to influence it for some time.

Genes, species, and demes therefore qualify as more-makers. Each reproduces a distinctive generic governing constraint regime that persists as an identifiable and coherent type of entity, with characteristic parameters, and embodied and enacted in a wide range of path-dependent tokens. The constitutive and governing constraint regime of genes is embodied in nucleic acid; it differs from that of social demes, where it is embodied in culture and traditions, which in turn differs from those for memes whose central enabling constraint is the web. Different material substrates provide different constraints; the enabling constraints that generate each emergent trait are different; they may operate on a variety of spatiotemporal scales; their properties and powers can be qualitatively different. But in each case, context-dependent constraint regimes can evolve to become increasingly far-reaching and/or long-lasting; in turn, their realized tokens and phenotypes become uniquely individuated in response to the particular path they traverse, the local context that affects them, and even the timing of each step of the process.

Some governing constraints (like those of demes) may be more far-reaching than those of genes; their attractors are wider. By being more flexible and ambiguous, they span more tokens, at more levels of organization. Others, like memes, may be more contagious, and the slope of their attractors is shallower, making dispersion and transmission easier. The walls of the attractors of yet others are more porous and permeable to surrounding attractors. They resonate more with others. This is particularly true if, as suggested earlier, the internet serves as context-independent vasculature of memetic culture: its global reach and speed are ideal channels that facilitate easy adoption, adaptation, and better fit in different contexts. Its network architecture is a powerful enabler; as a result, memes can quickly sculpt dramatically shape-shifting attractors worldwide. Contagion models aim to capture the dynamics of that architecture, given a set of specified constraints.

In sum, by making more tokens of a coherent genetic lineage, sexual reproduction carries an existing coherent dynamic into the future. By making more tokens of a coherent deme or meme, social and cognitive constraints can prolong its constraint regime even longer. In each case, the interdependencies persist because increasingly flexible governing constraints exercise top-down control over actual cases while allowing local context-dependent constraints to individuate each token.

The rest of this chapter describes a number of other constraints.

Density, Isolation, and Buffers

In addition to gradients, catalysts, feedback, replication, redundancy, and reproduction, density, isolation, and buffers are constraints that also increase the stability of a system's existing default governing constraints and thereby prolong its existence.

Density alone promotes clumping. Like gravity, it does not directly produce irreversible correlations, interactions, and interdependencies the way catalysts, feedback, and recursion do. But proximity and packing due to density might have made it more likely that context-dependent constraints would appear. Earlier I speculated that, cosmically, a local gravitational well's density might have altered the likelihood that a new kind of constraint would arise. The fact that at the subatomic level forces and fields are interactions supports this conjecture. Constructive interference of nearby atomic orbitals (Nordholm and Bacskay 2020) constitutes a new set of interdependencies, a new possibility space: molecules with the novel powers and properties of chemistry might have been the chance consequence of dense gravitational conditions at the atomic level. Alone they would have imploded into a black hole, but when combined with the

Pauli exclusion principle, a constructive interference pattern that could act as a novel second-order top-down constraint might have emerged.

With fifteen billion neurons crammed into the rigid skull and 2.5 meters' worth of chromosomes packed into each cell, there are analogous reasons to hypothesize that crowded conditions in biological systems might have similarly favored the appearance of context-dependent constraints and generated new interdependencies among brain cells and with the environment.[5] Feedback from the environment through reentrant signaling in densely packed conditions, for example, might have correlated and intertwined neural processes. The resulting streamlining and pruning during early brain development in response to the infant's actions, body weight, and other contextual constraints offers evidence of such dynamics. Some of these constrained correlations might have then gone on to become modularized as distinct types of structural neurons, of which there are at least one thousand.

Isolation

Darwin's round-the-world trip on the *HMS Beagle* prompted him to focus, however, not on density and novel correlations due to close packing, but on the role of isolation in the formation of new species. Although it cannot retard genetic drift within a population, *isolation* stabilizes the status quo by preventing the introduction of new and possibly destabilizing information. As a context-independent constraint, isolation delays the homogenizing pressure of the second law by keeping conditions away from equilibrium longer than otherwise.

Darwin's genius was noticing that, long term, isolation can also occasion divergent clusters of interdependencies and new constraint regimes.

Isolation comes in diverse forms. It can be geographical. Populations in geographically isolated locations, like the Galapagos Islands, or in remote continents, such as Australia, diverged from other populations of (what might have previously constituted) the same species. Fish in different lakes can evolve into distinct species. Darwin's beloved finches are the textbook example of this process. In isolated conditions where the homogenizing role of genetic drift and gene shuffling is limited, selection of reproductively favored phenotypes (beak shape, size, and strength) will evolve into a distinct species whose interdependencies diverge from those of earlier populations. Geographic isolation can enable the formation of even more complex types.

Isolation and the accompanying species divergence keep the second law at bay longer than expected. In contrast, interbreeding brought about by isolation paves the way for the reemergence of *latent constraints* in recessive genes. When contextual changes weaken existing governing constraints, incestuous breeding that would not occur under normal conditions might hasten the appearance of recessive traits. Possible realizations that were dormant resurface. The process, however, depends on the fact that the species, as a coherent type, is multiply realizable and variously embodied in actual tokens depending on contextual constraints.

Both species divergence and the resurfacing of latent traits appear to be evidence of an increasing role for context dependence over evolutionary time. The distinction between dominance and latency is context dependent; it is conditioned on an embedding context with respect to which the genes in question are dominant or recessive, manifest or latent. Latency, that is, is defined with respect to an existing contextually constrained type induced not only by the enabling constraints that generate it and the governing constraints that preserve its coherence, but also by the current context within which those constraints effectively tailor and modify outcomes. Dominance and latency in biology therefore enact *hybrid constraints*, which combine context-independent and context-dependent characteristics. Imposing or relaxing such constraints changes the landscape of conditional probabilities and therefore the events within it.[6] Because recessive is type-defined, and types, in turn, are contextually generated, recessive phenotypes surface or not depending on circumstances. Under conditions of reproductive isolation, the reappearance of latent constraints reflects gene shuffling statistics that, in a less diverse possibility space, make it more likely that recessive phenotypes will reappear. Of those that do, fitting in with the new conditions will be adaptive; the stressed type, too, will correspondingly evolve.

In isolated populations, resurfaced latent constraints and horizontal gene transfer can produce mixed outcomes. Some of these recessive phenotypes might have survival advantage and will be selected. But a higher prevalence of autosomal recessive disorders directly attributable to isolation and interbreeding is also more likely. Communities such as the culturally and geographically isolated Old Order Amish exemplify this dynamic. Changing the ratio of dominant to recessive genes by altered constraints can place unity of type at risk.

The central point here is that conditions in which latent constraints reappear and isolated species diverge need not be the direct consequence of random mutations alone. Genetic as well as epigenetic and epistatic information is encoded in multiply realizable and constrained interdependencies at numerous spatiotemporal scales; these establish conditional probabilities for gene activation, inhibition, expression, and so on—always conditional on context. Under certain conditions, those with a certain likelihood are dominant; under those same conditions, those marked by a different probability are recessive. Under entirely different conditions completely new phenotypes might appear without genetic modification. Actual phenotypes that are not metastable and fail to fit the context, of course, will not reinforce, repeat, or reproduce. The niche's overarching governing constraints will not embrace them. But the capacity to span, adapt, and surface a range of variants allows constraint regimes themselves to coevolve in tandem with the extant realizations. In a multidimensional state space, the combinatorics of multiple constraint satisfaction can be mindboggling.

As the human genome project confirmed, these ideas imply that type–token relationships are not one to one. Multiple realizability of types, abiotic and biotic alike, implies a range of variant tokens that are actualized or not conditional on context; it implies that interactional types span multiple paths to realizing the same emergent and collective properties.

Analogous dynamics also accelerate divergence in populations that are not geographically isolated. Differentiation keeps state space inhomogeneous, but differentiation due to isolation can come about due to ecological reasons. Food preferences can cause insects to feed in distinct types of trees. Over time, those insect populations become distinct. Similarly, differences in mating preferences even in mixed populations drive changes in the probability distribution of the various phenotypes. Distinct habitats form. Over time, gene pools diverge and produce "genomic islands of divergence" (Turner et al. 2005).

Recent research on two species of birds that share the same nature preserve in Argentina confirmed sexual selection (Campagna and Turbek 2021; Turbek et al. 2021). These two species of seedeater differ in plumage color and the details of their songs. Sharing 99.9 percent of their genes, brightly colored and tawny seedeaters interbreed freely in captivity. But they never interbreed in the wild. If they did, gene shuffling would homogenize their traits and prevent divergence. Whereas unconstrained sexual reproduction homogenizes a population, mating preferences and sexual selection are context-dependent constraints that change the proportion of latency to dominance. The evolution of mating preferences and sexual selection, in other words, indicates the emergence of a new context-dependent constraint. Once established, that new constraint regime is made manifest as new local troughs and hillocks in possibility space.

One sort of isolation can contribute to another: *geographic*, *cultural*, *religious*, or *informational isolation* can significantly restrict the reproductive pool from which mating preference selects. In the case of the Old Order Amish, the effective upshot of combining these various forms of isolation is *reproductive isolation*. Reproductive isolation brought about by mating preferences and other forms of sexual selection can also sediment and entrench differences, as will be discussed below.

As a reminder: these remarks are pertinent to our central concern, coherence-making, for several reasons: (1) neither mating preferences, isolation, density, nor sedimentation and entrenchment, as will be described below, are efficient causes, and yet they have consequences. They are constraints that generate, preserve, modify, and realize interlocking interdependencies. (2) They have consequences as constraints depending on the spatiotemporal context in which the entity in question is enmeshed and embedded. Even more to the point: (3) the above dynamics are possible only because the governing constraints of coherent interdependencies are multiply realizable and were generated by enabling context-dependent constraints.

Shielding organisms from gene shuffling and genetic drift generally results in species divergence. In addition to isolation, other constraints acting as shields include buffers and boundaries.

Buffers and Other Shields

For open systems that exchange matter, energy, and/or information with their environment, preserving coherence over time—prolonging a complex system's existence—is a question of sustaining their constitutive and governing constraint regimes despite and throughout those exchanges. As has been repeatedly noted, constitutive constraints stabilize interdependencies in the face of fluctuations and perturbations; they carry out that stabilization as governing constraints.

By adding extra context-independent constraints, buffers further stabilize existing constraints and delay thermalization.

Buffers are conditions that alter possibility space such that energy flows more readily in one direction than another—or does not flow at all. Buffers are not forces; they are add-on constraints that reinforce existing governing constraints by shielding complex systems from intrusion by extraneous forces. Buffers prevent potentially destabilizing elements, events, or information from gaining access. More precisely, buffers are impediments to energy flow. Indirectly, they strengthen boundaries and interfaces and thereby improve the likelihood of a coherent system's continued existence. Chemical buffers, for example, dilute the effects of threats to the system's coherence. Buffers are thus extra constraints that, under precarious conditions, help preserve the status quo.

Buffers need not be physical. Rate differences between a system and the wider context in which it is embedded can also dynamically buffer systems from their environment. In ecosystems, buffer species are distinguished by different cycling rates than other species—and the environment in which they exist. If predators can feed more readily on buffer species, either because there are more of them than of the usual prey, because they reproduce faster than the usual prey, or if there is a scarcity of the usual prey, rate differences protect the ecosystem's overall balance. High reproduction rates also buffer against population crashes by adding a context-independent constraint that allows lineages to temporarily outrun entropy. Again, rate differences are not efficient causes; they are constraints that generate and constitute distinct coherent dynamics.

Buffers can also be temporal. Audio lag time during live radio, television, and even Zoom calls prevents inappropriate or potentially illegal comments from being broadcast. Likewise, buffers need not be exclusively spatial. As we saw in the section on isolation, geographic isolation initially acts as a spatial buffer and brings with it its own constrained interactions; it can then do double duty as an informational buffer. But direct informational constraints such as censorship and limited access to sources of financial support or information also buffer the status quo from novelty that might destabilize the system's informational closure.[7]

Buffers can emerge spontaneously in response to context-dependent constraints. Early agent-based models of urban dynamics showed how neighborhood segregation naturally arises from interactions constrained in particular ways (Schelling 1971; Hatna and Benenson 2012). Buffers are also common in computer coding, where data are buffered in a separate storage area for future editing. In chemistry, liquid–liquid phase separations demonstrate the self-organization of buffers. Some chemical solutions also maintain their pH relatively stable by buffering against pH change. Stable pH conditions serve as a background constraint that allows enzymes that require precise pH levels to function.

The distinction between buffers and boundaries is hard to draw for open systems. The term buffer is traditionally used to refer to separations caused by material substrates. Expanses of ocean buffer the Galapagos from invasive species. Mountain ranges and water obstacles (including artificial moats) are called buffers, as is the demilitarized zone on the Korean Peninsula. But buffers need not be materially based. Zoning regulations and financial redlining practices can deliberately include construction and financing rules that keep races separate and thereby consolidate segregation.

To summarize: isolation and buffers are constraints that support persistence by protecting a system's zone of metastability and continued existence, which they do by acting as shields against threatening input. Isolation and buffers bring about this added protection through context-independent constraints that guard existing coordination dynamics from environmental threats that might precipitate their dissipation. Feudal lords did the same with castle keeps and moats.

Once again, it is tempting to conjecture that the universe is characterized by a general trend, from rigid boundaries and physical gaps to interactive interfaces operating as *gating constraints*. Just as rigid walls of prokaryotes gave way to more permeable membranes of eukaryotes, so too moats and Great Walls of China gave way to . . . safe conduct letters of transit and visas? In each case there emerged dynamic interfaces that actively negotiate relations between the inside and the outside and thereby satisfy multiple constraints. If this conjecture were confirmed, it would be worthwhile to study the role context-dependent constraints played in that trend. Increasing complexity suggests increasing reliance on context dependence.

Motility and Migration—The Relaxation of Constraints

Human and animal populations as well as convection cells can exhaust or deplete existing energy gradients that nourish them and which they tap to survive or persist. Such risks to enabling and governing constraints of existing coherent dynamics can destabilize their effectiveness; interdependencies begin to decohere and disintegrate. Entire metastable dynamics must adapt and evolve in the face of such threats; otherwise, extant governing constraints will inevitably weaken. Invasive species whose constraint regime offers a significantly better fit with current conditions can outcompete autochthonous but threatened ecosystems. They do not become buffer species; they wipe out native ones.

In contradistinction to reinforcing existing constraints, relaxing them might open the door to new enabling constraints. Motility, for example, opened[8] new degrees of freedom when existing and restrictive constraints that kept plants in a fixed location were relaxed. Relaxing those constraints was tantamount to making room for the appearance of new enabling constraints. Affixed to a location, plants change their shape throughout their existence. Animals, in contrast, trade shape shifting for the ability to change location; as adults, their shape changes little. Different enabling constraints induce different interlocking constraints, which realize different forms of life. Beginning with chemotaxis, cellular locomotion is a novel form of life induced by the resulting phase transition enabled when barriers to energy flow were relaxed. New options emerged: moving toward a higher concentration of a diffusible substance or away from it. The appearance of motility in living things became a new enabling constraint that opened possibility spaces with previously untappable free energy. It changed things completely.

In response to other context-dependent constraints, some animals take motility one step further; they become migratory species, thereby expanding the spatiotemporal reach of their constraint regime. Migration can be either a one-off phenomenon or seasonal. The latter is indicative of expanded governing constraints cued to context-dependent signals such as ambient temperature or light, or the availability of resources. In response to gradients, migrating populations gravitate toward more favorable environments when their existing niche is threatened (Agosta and Brooks 2020).

From hominins over two million years ago to human migrations today, mass movement patterns are evidence of resource gradients operating as context-independent constraints. Because they are embedded in an extended ecosystem dynamic, populations respond to contextual cues and, as a result, can precipitate mass migrations. They move toward improved resources and away from threats. Events in the U.S. southern border illustrate how stressful conditions at home, combined with the perception of accessible opportunity in the United States, provide multiple constraints that take a system far from equilibrium to a threshold of instability and then over it to new forms of interdependence.

Migration is directed toward adjacent possible areas where there are (or are perceived to be) available resources or fewer threats. All these terms must be understood as referring to spatiotemporal constraints and ultimately cashed out by thermodynamic considerations. In an era of airplanes and now space tourism, even the term *adjacent* must be redefined. People will migrate to areas where they know others, often from the same village. Here, adjacent translates into known and culturally compatible overlap, not physical distance. The general point here is that contextual considerations contribute to outward as well as internal migration by relaxing and reconfiguring existing enabling constraints, including overall constraint regimes and the topology of possibility space. Top down, this reconfiguration changes the beliefs, dispositions, and behavior of individuals caught up in that dynamic.

Outmigration renews a population's possibility space. Once a population migrates, its constraint regime imports close-enough features of the new and previously unfamiliar habitat, whose own constraint regime will simultaneously intrude into the population's earlier constraint regime and thereby co-create a wider niche or adaptive space (Woods 2019). Both coevolve. The transformation of the sociocultural landscape of the southwestern U.S. border, or of Miami-Dade County (Florida), over the past sixty years in response to migration flows provides a dramatic case study of this process. The oft-heard phrase, "Miami is the capital of Latin America," implies a wider set of financial and cultural interdependencies whose governing, top-down constraints (many of which are tacit) are affordances of the U.S. legal and political system. Its fiscal and jurisprudential framework affords the metastability and overlapping habitat necessary for hemispheric trade relations. But both habitat and residents coadapt as a result.

It is not too far-fetched to propose that the translational motion of hurricanes and the oscillating waves of BZ reactions are physical and chemical precursors to animal motility in general and human and animal migration in particular. In contrast to their rotational motion, the forward, translational motion of hurricanes is sometimes called propagation, making the analogy with disease spread explicit. This is possible because the paths of migration, epidemics, and hurricanes are not random walks. They are enabled and governed by multiple constraints. The direction and speed of cyclones and hurricanes are vectorial coordination dynamics dependent on constraints; these generate a tendency to move toward warm areas and away from frigid air. Likewise, epidemics of infectious diseases will spread to areas with increased population density and low rates of inoculation or immunity, for example. People move to areas where they know others, or of safer conditions. The upshot, once again, is that enabling constraints generate patterns of matter, energy, and information flow; governing constraints then preserve the coherence and persistence of those patterns by exploring/exploiting previously inaccessible regions of adaptive space. In turn, the dynamics expand spatiotemporally and last longer than they would in the absence of new coherent interdependencies or tacked-on constraints such as buffers, isolation, and the capacity to move.

This reinforces the point that niches and habitats are not existing sites, prebuilt recesses in a wall waiting for fit organisms to show up and occupy them. Niches and habitats—abiotic, natural, and social—are co-constructed contexts; they are coordination dynamics interwoven by constraints. Those interdependencies manifest as a contextually coherent type that underpins novel affordances for multiply realized tokens (Gibson 1975; Carello and Turvey 2002; Chemero 2003, 2009). Those interdependencies then select for actualization from among the range of options afforded by the new interactional type.

Failure to understand the dynamics of contextually constrained niche formation and modification will get a lot of the actual interdependencies wrong. Failure to appreciate the background constraints of entrenched economic, cultural, and political conditions against which context-dependent constraints operate will get yet other interdependencies wrong. Failure to recognize tacit constraints risks bottom-up upheavals when governing constraints are unresponsive to context. As always, enabling and governing constraints intertwine simultaneously and over different scales, requiring multiple constraint satisfaction. Failure to track underlying constraints responsible for the invariances gets the ontology wrong. If it is to have any hope of being effective, domestic and foreign policy must get these social constraint dynamics right.

Templates, Frameworks, Scaffolds, and Affordances

The concepts of scaffolds, frameworks, templates, and affordances highlight important forms of constraint (Wimsatt 2007; Caporael, Griesemer, and Wimsatt 2014; Bickhard 1992; Carello and Turvey 2002). They describe specific varieties of constraints in social and biological settings. Some are context dependent; some are not. Some are enabling constraints; some are governing constraint regimes. All describe varieties of influence other than mechanical or forceful causes. They are constraints that inform cognitive and behavioral possibility spaces and guide realizations to completion. They do so by presetting and then continuously adjusting the likelihood of what is possible and what is likely.

Affordance theory (Gibson 1975; Turvey, Shockley, and Carello 1999; Chemero 2003) was among the first to view psychological capabilities in ecological terms. *Affordances* are relational properties that function as constraints by weaving together an organism's capabilities and propensities and its world. Affordances are the products of enabling constraints that create novel interdependencies and opportunities. Like biological niches, they structure an organism's psychological ecology, dispositions, and behavior patterns such that it can act more effectively in that world. To use a common example, for Westerners, chairs afford opportunities for sitting. For the Japanese, tatami mats afford opportunities for sleeping. Individuals embedded in those worlds recognize those items as affordances and act appropriately (Chemero 2003. Also see chapter 13 of this volume, the 4E approach).

Because they are formed by context dependent and ecological interdependencies, affordances can activate in sequence in response to other temporal and contextual constraints. Walking is not afforded to newborns, but it is to toddlers (Thelen and Smith 1994). Differentially activated constraints make possibility spaces even more complex and effective. Superior design is all about incorporating transparent affordances and enabling constraints into products and services, from software and business development to commercial and industrial artifacts and communities of practice generally (Bloom 2015; Burgauer 2022b). Under the guidance of English American experimental psychologist Michael Turvey, UConn's CESPA lab used the concept of affordances to design prosthetic devices that build in enabling constraints to improve perception and action.

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The *Oxford English Dictionary* (*OED*) (June 2022) states that, used metaphorically, the concept of *framework* suggests the idea of "fitted arrangements." In this sense, frameworks are like affordances and principles of conceptual organization; they format behavior by presetting definitions, parameters, and category boundaries—in short, by initializing cognitive and behavioral constraint spaces within which certain ideas and actions will be possible or viable, and others not. Conceptual frameworks allow room for adjustments and arrangements before the fact; not so much afterward. Like IT platforms, conceptual frameworks initialize rules and parameters—the background constants—on which instructions and protocols rest. In short, frameworks are constitutive and governing constraints that structure, coordinate, standardize, and otherwise adjust relations among the concepts and assumptions they organize. As a result, these organize coherent conceptual landscapes.

Metaphorically speaking, frameworks are looser than molds and templates. Because molds and templates guide behavior to ensure a certain outcome, they incorporate motivational constraints, which frameworks do not, at least directly. Templates actively direct behavior while it occurs; they also limit the possibility of changing the template itself once the process has begun. Chapter 7 described how folding back onto itself creates templates for protein folding. Templates operate throughout the biotic world. Prions (proteins, initially thought to cause only harmful effects such as the neurological disorders Creutzfeldt-Jakob disease and mad cow disease) have recently been found to empirically implement template formation. Under certain conditions, a protein called CPEB folds back into a prion, which then grows a fibril that permanently alters synaptic structure. Described as *self-templating*, this constraint-directed process is hypothesized to be responsible for a protein-based inheritance mechanism—a form of long-term memory that is independent of DNA (Brahic 2021).

Scaffolding

Scaffolding has recently become the object of attention of practitioners in fields as unrelated as theoretical biology and business management. American architect Ann Pendleton-Jullian (2020, 280) maintains that scaffolds are a more generalizable concept than frameworks. Both, however, inform. The following section draws heavily from foundational work on scaffolding by Wimsatt (2007); Wimsatt (2014) in Caporeal, Griesemer, and Wimsatt (2014); and Bickhard (1992).

Pioneered by Soviet social constructivist Lev Vygotsky and developed by American cognitive psychologist Jerome Bruner, the metaphor of instructional scaffolding was first applied to structured interactions between teacher and pupil to guide learning. The activity of scaffolding is a context-dependent constraint that, catalyst-like, facilitates information, matter, and energy flow—in a certain location, in a certain direction. Teacher-provided scaffolds offer points of equilibria and pathways that make the next step easier, smoother, or quicker for the pupil. In the formation phase, then, scaffolds operate as enabling constraints that assist in taking projects to completion. Scaffolds set up affordances and offer nearby points of equilibrium (Bickhard 1992) or "zones of proximal development" (Vygotsky 1978) that stabilize progress and make next steps more accessible.

The stabilizing power of scaffolds is key. Scaffolding's simultaneously enabling and stabilizing constraints make it more likely that goal-directed activity will reach conclusion. Scaffolding is therefore critical to the successful completion of many complex projects. Without them, the project might not be finished; it might not even get off the ground.

Whether taken as metaphorical or literally, *ratchets* are also scaffolding mechanisms. The asymmetry of a ratchet's gear teeth preserves and stabilizes each achieved step. By preventing backsliding and allowing movement only in the forward direction, ratchets make it easier to reach the next step. Ratchets and scaffolds thus reinforce sequential enabling constraints that make advancing easier by providing a steadily growing platform (Bickhard 1992) from which to launch the next step.

By affording nearby "points of stability" from which to continue building or growing in the right direction and at the right pace (Bickhard 1992), scaffolds and ratchets are also like affordances; they embody context-dependent constraints that bias the likelihood of which future events become possible, can occur more readily, or be performed or structured in a particular way. They set up interdependencies whose joint probabilities prevent disruptive perturbations from waylaying long-term projects. In doing so, they contribute to the formation and persistence of new interdependencies. They contribute to coherence-making.

By characterizing scaffolds as "muting, blocking, or suspending selection pressures," Bickhard 1992 implies an ecological perspective. Scaffolds afford guidance and progress only for those who are cued to the opportunities of a particular context and artifact. As mutually constraining and constrained processes, scaffolds are therefore afforded by the shared interdependent constraint regime in which both agent and scaffold operate. The adaptive space of teacher and student, for example, is already socially structured even before the two walk into the classroom. Similarly, Asia's bamboo scaffolds in skyscraper construction take advantage of a plentiful and renewal resource, but only if builders are attuned to the requirement that bamboo must be pretreated against fungi and insects to function as scaffolds at all.

Scaffolds and affordances therefore facilitate natural and cultural evolution; they make stepwise progress easier by preselecting and biasing the user's next steps. Cultural rituals and taboos do the same for members of a community; mourning and grieving traditions such as sitting shiva and ceremonial wakes no doubt serve that function as well. By weighting the possibility landscape, preset constraints allow members of a community not to rethink each step on their own. Coherence-preservation is facilitated as a result.

When a coherent dynamic's governing constraints weaken, its gear teeth destabilize and become unable to prevent it from degrading into thermal equilibrium. This understanding of context-dependent constraints is congruent with Bickhard's statement that artificial tools and even entire cultural environments can be considered scaffolds that facilitate the construction of "a structure distributed in space" (Bickhard 1992); such constraints are affordances, "adjacents possible" that lower barriers to energy flow and thereby make next steps more accessible. Scaffolds and scaffolding, molds and templates are context-dependent constraints with ratchet-like properties.

By including temporal constraints, we can extend Bickhard's insights to include scaffolds that aid completion of "structures distributed in time," such as the constraints of ontogenetic development and lineages. (For differentially activated constraints, see generative entrenchment in chapter 10.) From regulatory genes to yearly family rituals or once-in-a-lifetime ones like baptism, temporal constraints generally provide time-based scaffolding and affordances that help complete processes and keep social dynamics coherent. Recall the precise sequence of steps required to prepare cassava root and nardoo spores. Such metastable sequences are temporally coded sequences that, as scaffolds, lessen the effects of external insults; they also minimize having to figure out everything from scratch each time. In consequence, they mute selection pressures. Entrenched constraints stabilize those existing metastable sequences and dynamics. They also facilitate the appearance of other enabling constraints that generate major transformations. Entrenchment and modularity will be explored in more detail in chapters 10 and 12, respectively.

Types of Scaffolds

Like the term constraint, of which scaffolds are one realization, *scaffold* itself is ambiguous. It can refer to either a process or a result. The classical notion of scaffolds, of course, is *artifact scaffolding*, such as traditional architectural scaffolds, those externally manufactured and assembled objects that facilitate the construction of tall buildings. They bias the flow of energy and matter in a particular direction, in a particular sequence. *Architectural scaffolds* are thus prebuilt context-independent constraints that take the possibility space away from equiprobability. Following Bickhard, national monuments and museum collections of material culture can also be considered scaffolds that promote cultural transmission. They encourage us to see history in a particular way.

Asking the right questions in the right order at the right time, on the other hand, is a *pedagogical scaffold* that does not produce an artifact. Other varieties include *infrastructure scaffolding*, such as transportation and utility networks, and *developmental scaffolding*, such as the Peace Corps and Teach for America organizations. Some of these produce an artifact; others do not. Capacity building is a combination of infrastructure and developmental scaffolding.

Cellular cytoskeletons and vertebrate backbones, too, are context-dependent organic scaffolds. They provide stable, and therefore more durable, spatial configurations that serve as frames for the construction of organic structures. Their structural soundness and configurational stability generate novel (vectorial?) enabling constraints that guide processes along the correct path on which to build or repair further stable structures. In the abiotic domain, metastability likewise prolongs constraint regimes and thereby allows future increases in complexity to occur.

For purposes of this book, then, scaffolding, scaffolds, affordances, frameworks, templates, and molds are significant for their role as constraints. They facilitate, bias, and guide behavior—toward directed goals or end points, along precise sequences of stable steps. They embody implicit instructions, sequences of stepwise spatiotemporal constraints. Under precarious conditions, scaffolding also helps ongoing developmental processes avoid dissolution and successfully reach finality or even get started. Once set up, scaffolds serve as background constants of possibility space. Scaffolds and scaffolding are thus hybrids of context-independent and context-dependent constraints.

The metaphorical use of the term scaffolding is commonly organized around the workings of architectural scaffolding. In consequence, it is often characterized as temporal and temporary resources that provide a platform from which to ratchet development generally, not only learning (Caporael, Griesemer, and Wimsatt 2014, 2). However, thinking of scaffolds generally as temporal and temporary (as is the case in architectural and learning scaffolding) is limiting. Not all scaffolds (as enabling constraints) are temporal or temporary; even external architectural scaffolds can become integrated into the structure they helped construct. Flying buttresses of Gothic cathedrals are one such example.

Cynefin founder David Snowden and architect Pendleton-Jullian (2020) identify three additional types of scaffolding: keystone scaffolds, neural scaffolds, and nutrient lattices.

Arch construction is enabled by a particular form of architectural scaffolding, the keystone. Once in place, *keystones* become a permanent point of stability from which further construction can proceed. They become, in other words, permanent scaffolds for future growth. *Nutrient lattices*, on the other hand, are temporary. Applied to burn wounds in skin grafts, nutrients embedded in the lattices promote collagen production. As the body produces more collagen, “the connective tissue works its way up the artificial scaffolding, slowly building up new dermis. Over time, the artificial scaffolding dissolves away leaving no trace of the lattice."[9] This is an example of efficient causes (nutrients and metabolism) guided by scaffolds or affordance-like constraints (lattices and collagen).

Scaffolding that starts out as an external artifact and boundary condition can also become incorporated into the system itself without dissolving. Sometimes it is even integrated into the structure itself and becomes an internal constraint that confers stabilizing oomph and thereby contributes to the structure's persistence. For example, artificial bioactive lattices implanted to encourage bone growth do so as porous templates. As new growth infiltrates the interstices, the artificial lattice becomes permanently incorporated into new bone (Pendleton-Jullian and Brown 2016). The location, orientation, and size of a lattice's pores—their arrangement—embody its template function; these are enabling constraints. Once woven into new bone, they become components of the constitutive/governing constraints of the skeletal system.

Boundaries between scaffold and system, between system and environs, and between constraints and overall niche reflect differences in constrained interdependencies. As the prairie grasslands example illustrated, when feedback loops extrude into the environment or, which amounts to the same thing, import the environment into the dynamics, the dichotomy of internal versus external becomes irrelevant to any definition of scaffolding. It is the informational import of scaffolds—the constitutive or governing constraints that emerge from interwoven enabling constraints—that constitutes the effective interface between scaffold and scaffolded. It initializes the gating criteria of that constraint space as well as the settings that control action.

Whereas scaffolds enable process completion, prosthetic devices such as crutches, hearing aids, and artificial limbs as well as prescription eyeglasses and implanted lenses contribute to partial or full restoration of function. They are *restorative enabling constraints*. Their design affords links whereby emergent properties such as locomotion, vision, and hearing can be reestablished. What begins as a context-independent constraint becomes a context-dependent constraint that integrates new pathways into the coherent dynamics and constraint regime that embody a function. Implanted, *neuromorphic prostheses* (a variety of *neural scaffold*) that incorporate machine learning can become, with training and use, second nature, their deployment as effortless as the organic limb they replace.[10] Nowadays, brain computer interfaces (sometimes referred to as "brain–machine interfaces," or BMIs, when the signals are recorded by implanted sensors) can control a robot arm in real time. *Stentrodes,* electrode arrays inserted into blood vessels in the brain, monitor neural activity in part of the cortex. In time, the information conveyed by those implants becomes seamlessly incorporated into the subject's second-order, top-down constraint regime of motor activation: by thinking words or sentences that are then transcribed to a computer, patients can email, use apps, do online banking, and even turn the lights on and off in their house.

Alternating between *external* and *internal scaffolding* is a common pattern in nature. The transition from external to internal can be a form of coopting, as when external constraints are brought onboard and their function is internalized. Moreno and Mossio (2016) characterize the process of internalizing or coopting previously external boundary conditions as shanghaiing them and incorporating them as internal ones. When mitochondria were engulfed into bacteria, the former's enabling constraints for energy production were effectively coopted. The resulting interdependencies and new governing constraints became a new type of organism, eukaryotes. In the process, the rigid wall of the earlier prokaryotes cells also transformed into the eukaryotes' flexible but structurally integral combination of permeable cell membrane plus endoplasmic reticulum and cytoskeleton—an internal scaffold. As an active interface, this new structure is a constraint structure consisting of multifunctional microtubules, intracellular filaments that shape the cell, assist in intracellular transport, and even guide mitosis to ensure the cell's coherent structure is correctly replicated. In effect, the microtubules have become internalized scaffold constraints that prevent the cell's internal but mutually dependent components from equilibrating. As a curious aside: images of cell cytoskeletons are remarkably similar to images of the webs of cosmic dark matter mentioned earlier that appear to provide an invisible backbone that determines the hidden structure of the cosmos (Kruesi 2013).

We can suppose that, in analogous fashion, the external scaffolding of invertebrate exoskeletons (think marine seashells and horseshoe crabs) was shanghaied and evolved into the internal scaffolding of vertebrates, organisms with a more complex constitutive constraint regime. Even regulatory genes today are hypothesized to be modular encapsulations of what might have earlier been external constraints.

Once again, it is not entirely unreasonable to conjecture that such cooptation and shanghaiing of external constraints might represent a general trend that goes from externally set and rigid and impermeable boundary conditions of Bénard cells to endogenously generated and more malleable, porous, and internalized constraints whose most recent manifestation is the emergence of self-constraint in living things.

If so, closure of constraints in living things, as described earlier, constitutes the emergence of a form of *self-scaffolding*.

More-making makes more tokens of a coherent type, but closure of constraints ratchets the process to one that *self-scaffolds as self-constraint*. Closure of constraints self-constrains, self-scaffolds, self-constructs, and self-maintains interdependent processes in dynamic but steady nonequilibrium. Moreno and Mossio (2016) note that the being of living things "is their doing." The interweaving of these various forms of constraint integrates and preserves the interdependencies that define living things as the self-determining and autonomous variety of self-organizing process.

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