Autogenesis

From constraint to regulation

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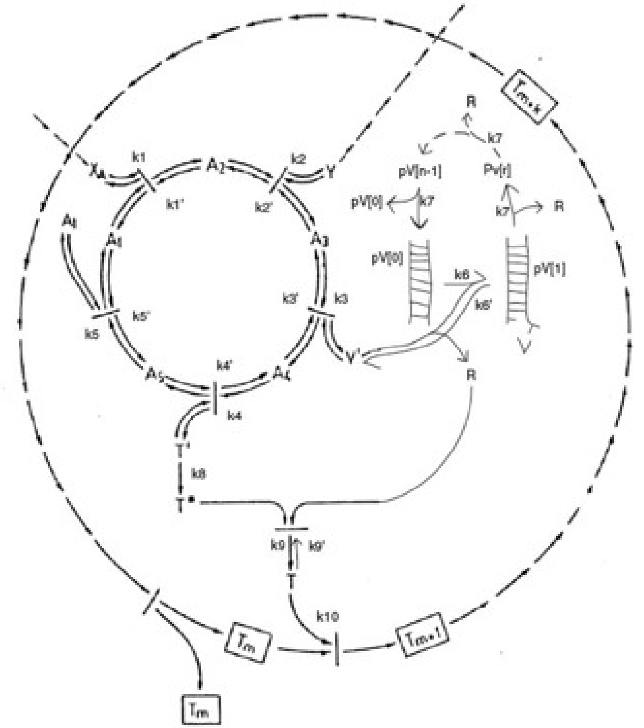
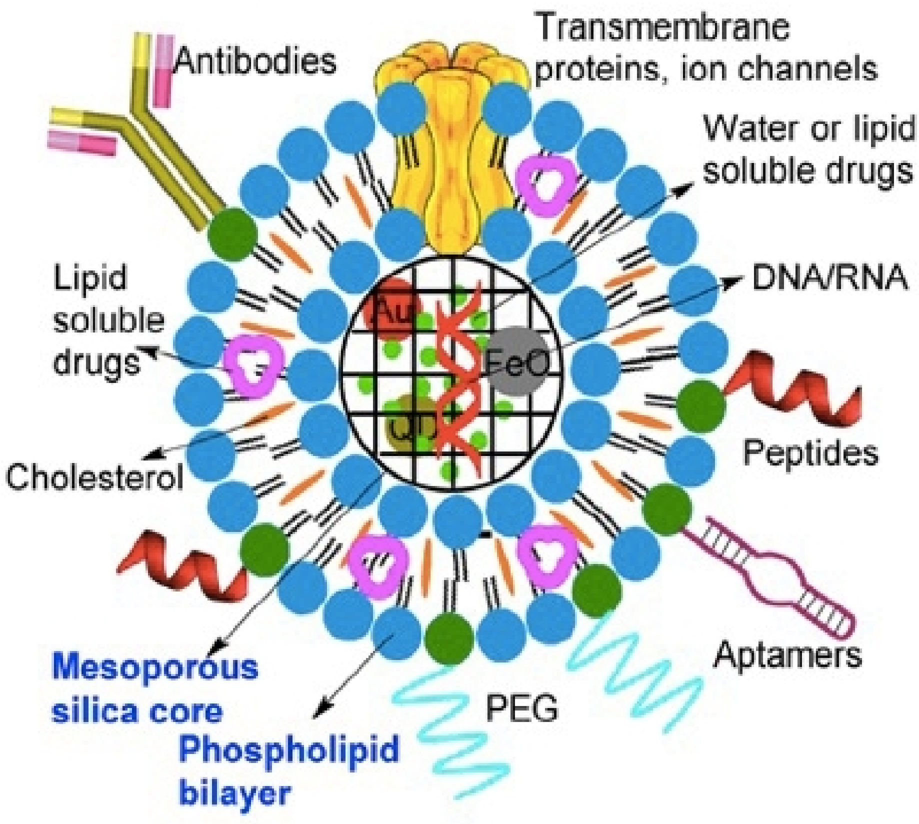
“Minimal Cell” logic



Tibor Ganti’s
Chemoton (1971)



Complex protocell

- Trying to reverse engineer the origin of life leaves us with too many incredible coincidences to explain

Eigen's Hypercycle

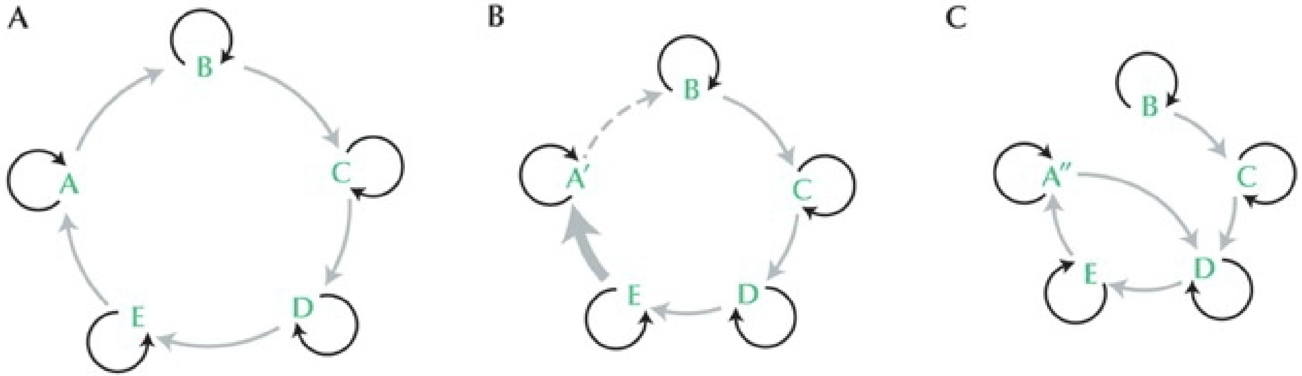


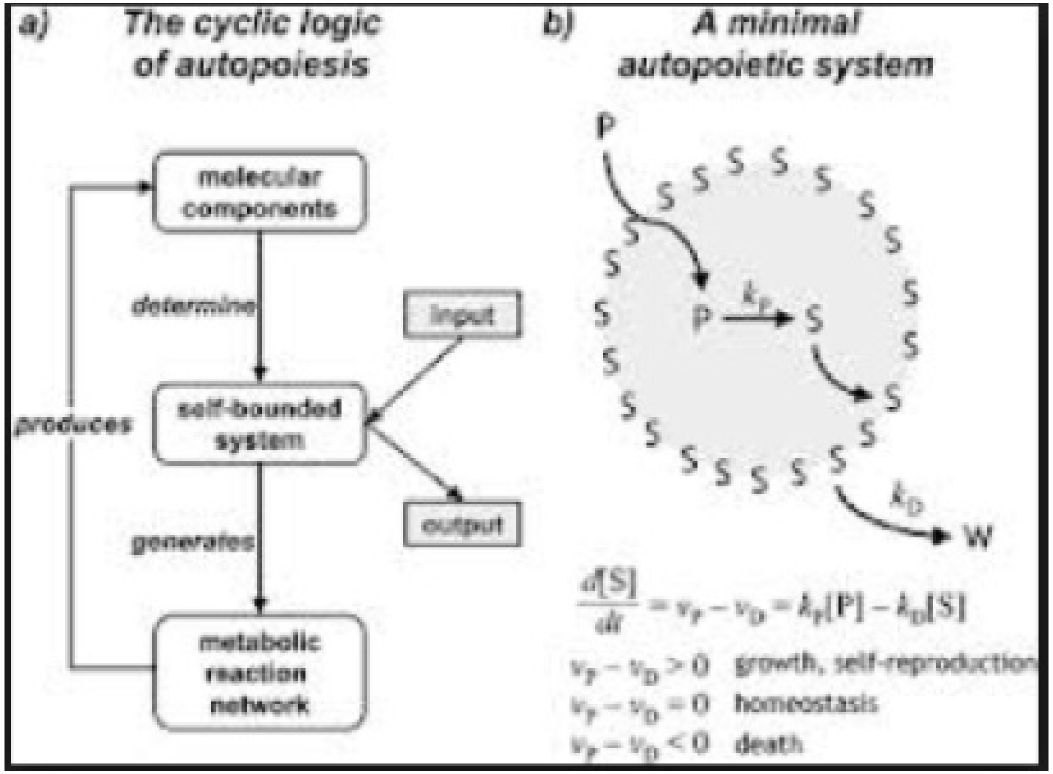
FIGURE 21.36. Hypercycles allow more genetic information to be replicated, but are unstable in several ways. (*A*) Several different replicating molecules (A, B, ... , E) can coexist in a population if they aid each others' replication: A helps B, B helps C, ... , and E helps A. This help could take many forms: provision of some metabolic product, directly aiding replication, etc. What is important is that B replicates faster as A increases in concentration, and similarly for the other links. Such diffuse mutualisms are a familiar feature of ecosystems (trees provide leaf litter for earthworms, which in turn improve silt structure and so aid trees) and are plausible for molecular ecosystems as well. (*B*) Hypercycles are vulnerable to invasion by variants. Compared with A, the variants (A′) gain more from help by other species (E) and provide less help to others (B). (*C*) Hypercycles also tend to lose members (B, C), if variants (A″) arise that sustain a shorter cycle.

- Too simple and there is no systemic integrity to provide a coherent unity able to preserve itself

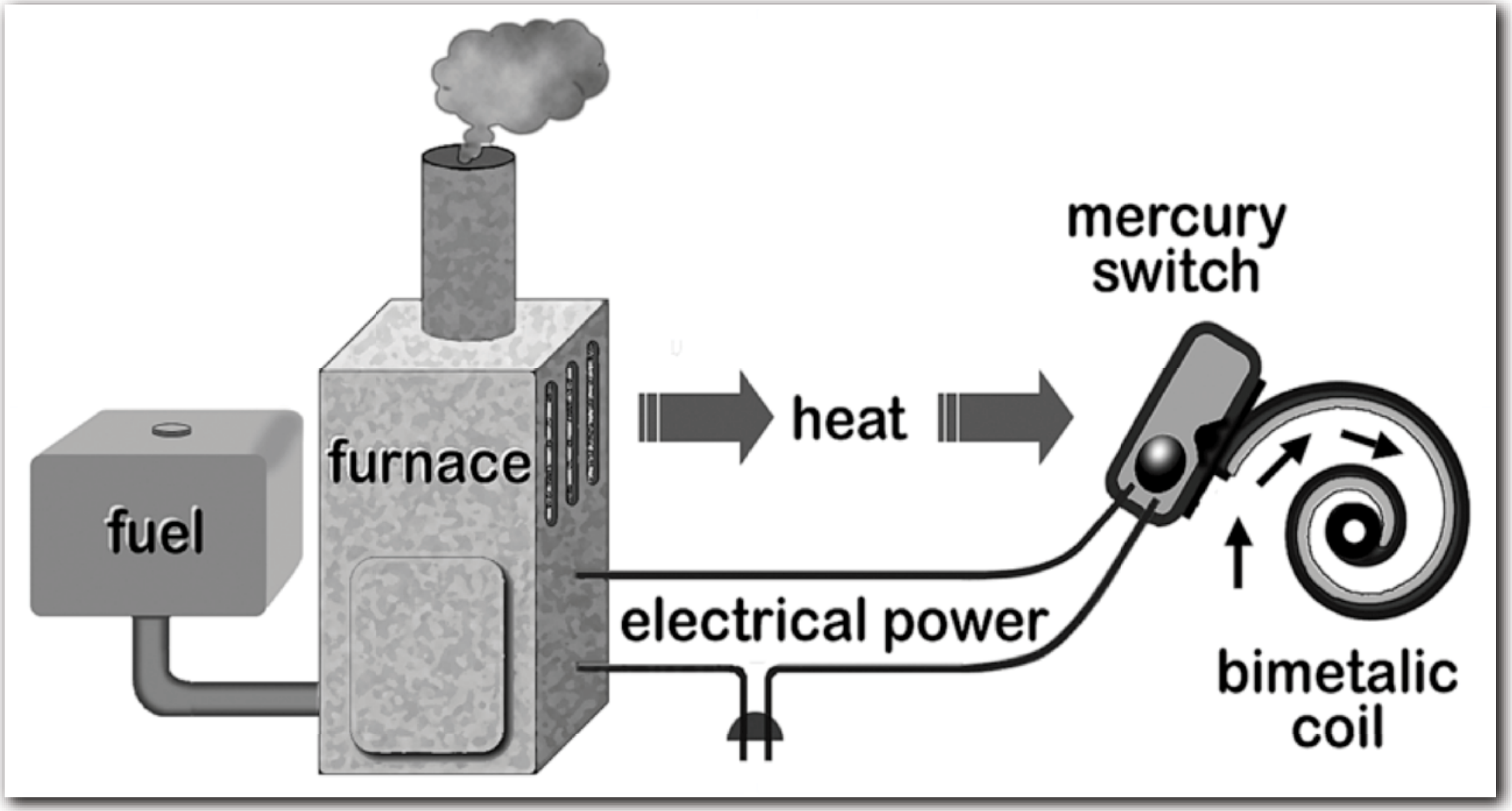
Autopoiesis ("self-fabrication")

> An autopoietic system—the minimal living organization—is one that continuously produces the components that specify it, while at the same time realizing it (the system) as a concrete unity in space and time, which makes the network of production of components possible. — **Francisco Varela**

- Autopoiesis *describes* what must be true of an organism *without explaining* how it can be accomplished.
- Specifically, it lack an account of internal regulation and what determines its unity.



Does referential information circulate in a cybernetic system?



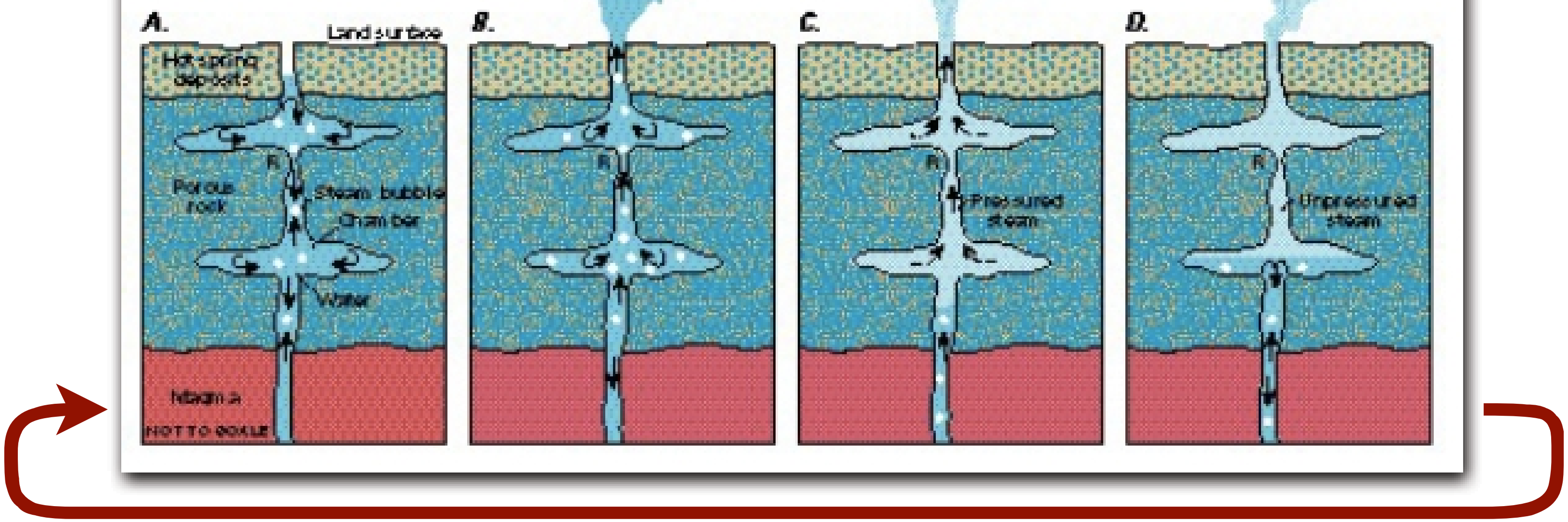
- At each step a difference in one feature makes a difference in another that results in convergence of the system toward a set target state when perturbed.

“Teleonomy” is parasitic function

- There is *nothing intrinsic* to the causal linkages (or their circularity) in a cybernetically organized system that warrants treating its component relationships as *functioning for* or conveying *information about* anything.
- This is not resolved by simply embedding a cybernetic system in a higher-order cybernetic system (e.g. second-order cybernetics).
- This only leads to vicious regress, which ultimately can only be resolved by appealing to some form of methodological dualism (e.g. cyber-semiotics, pan-semiosis, panpsychism, mysterianism).

What if the cybernetic system forms spontaneously?

A geyser cycle maintains internal temperature and pressure within certain limits with respect to changing ground water conditions by erupting at a certain threshold. Its feedback structure is an accident of geology.



- The difference between *accidental cybernetics* and *designed/evolved cybernetics* is that achieving a specific attractor dynamics did ***not*** contribute to the work that organized the accidental system.

Redefining teleo-function

* Proposal: a system exhibits teleo-functional (i.e. semiotic) properties only if the constraints that it generates play a primary constitutive role in generating its organization, including this same capacity to generate these constraints.

Emergent dynamics approach

1. Homeodynamics (thermodynamics)

   Spontaneous constraint dissipation, reduction of correlation, loss of symmetries, equilibration

2. Morphodynamics ("self-organization")

   Amplification of system-internal constraints/regularities due to the persistent extrinsic reversal of spontaneous dissipation

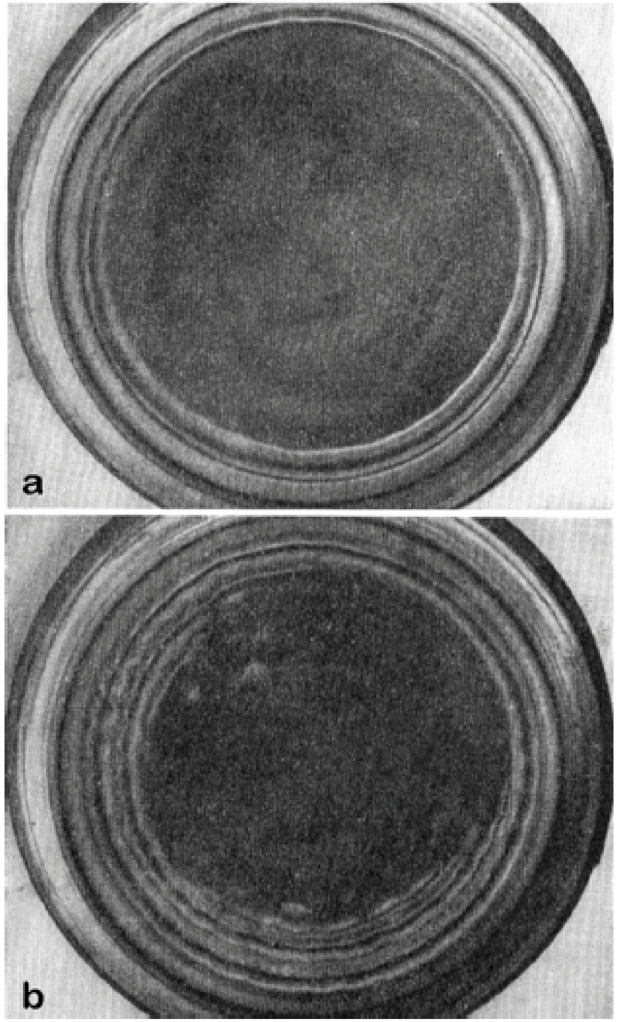
3. Teleodynamics (life, evolution, semiosis)

   Self-reproducing/maintaining constraints on the synergistic interdependent coupling of morphodynamics

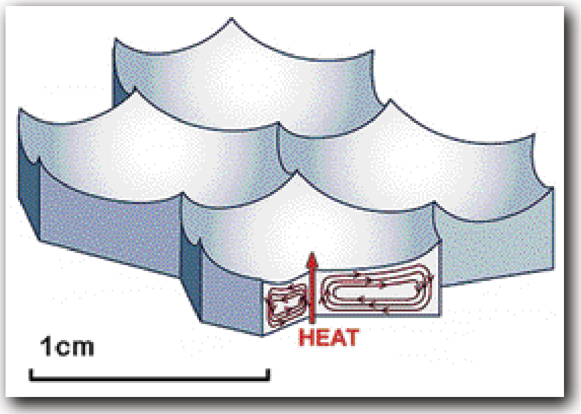
e

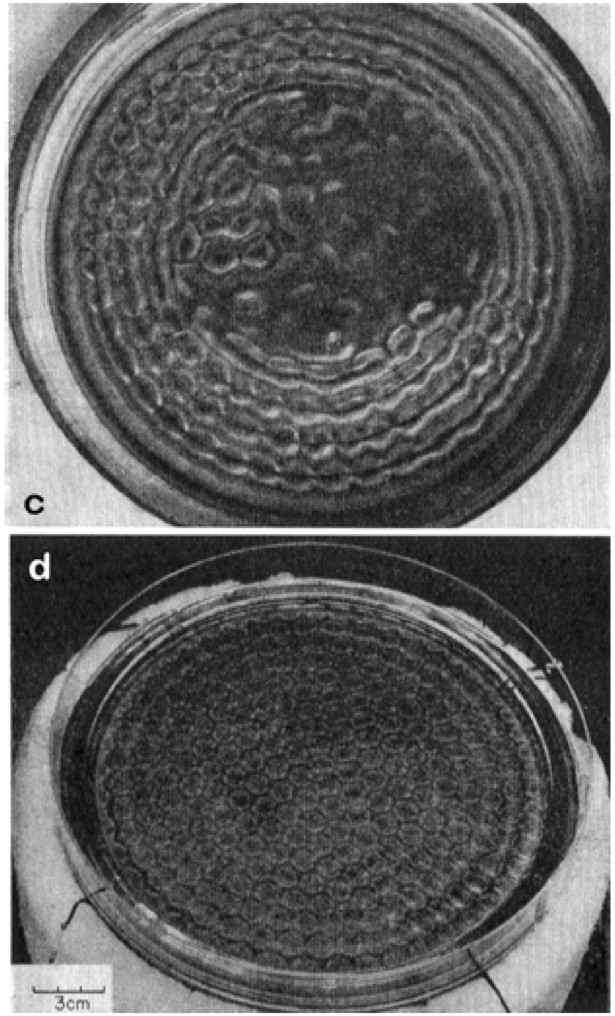
e

Morphodynamics ("self-organization")



Rayliegh-Benárd convection cell formation in a dish of heated oil

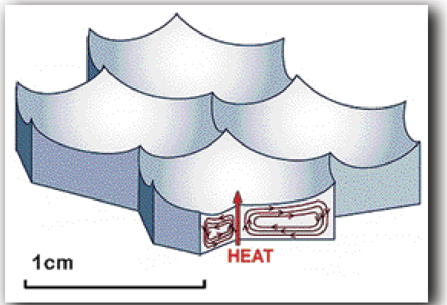




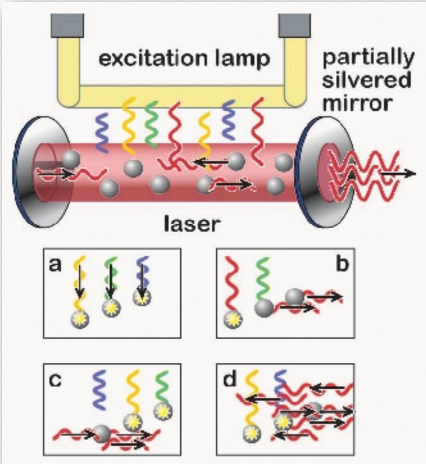
- It takes time for a morphodynamic attractor to form under the influence of constant extrinsic disturbance

Maximum entropy production (MEP)

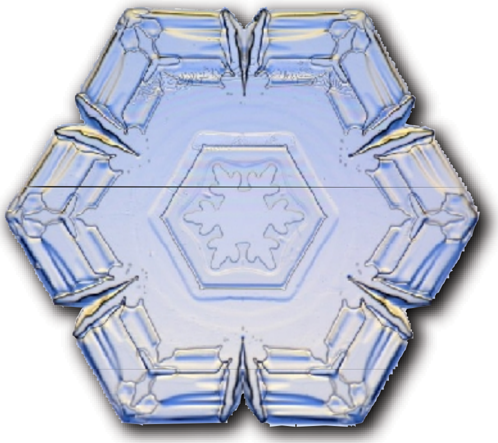
- Self-organizing processes develop in persistent far-from-equilibrium conditions
- Persistent perturbations induce amplification and propagation of constraints that align dynamics with minimal total dissipation-path length; thus least work & MEP.
- Self-organized processes are special converging types of non-linear dynamical processes which are often unstable and chaotic.



Rayliegh-Benárd convection



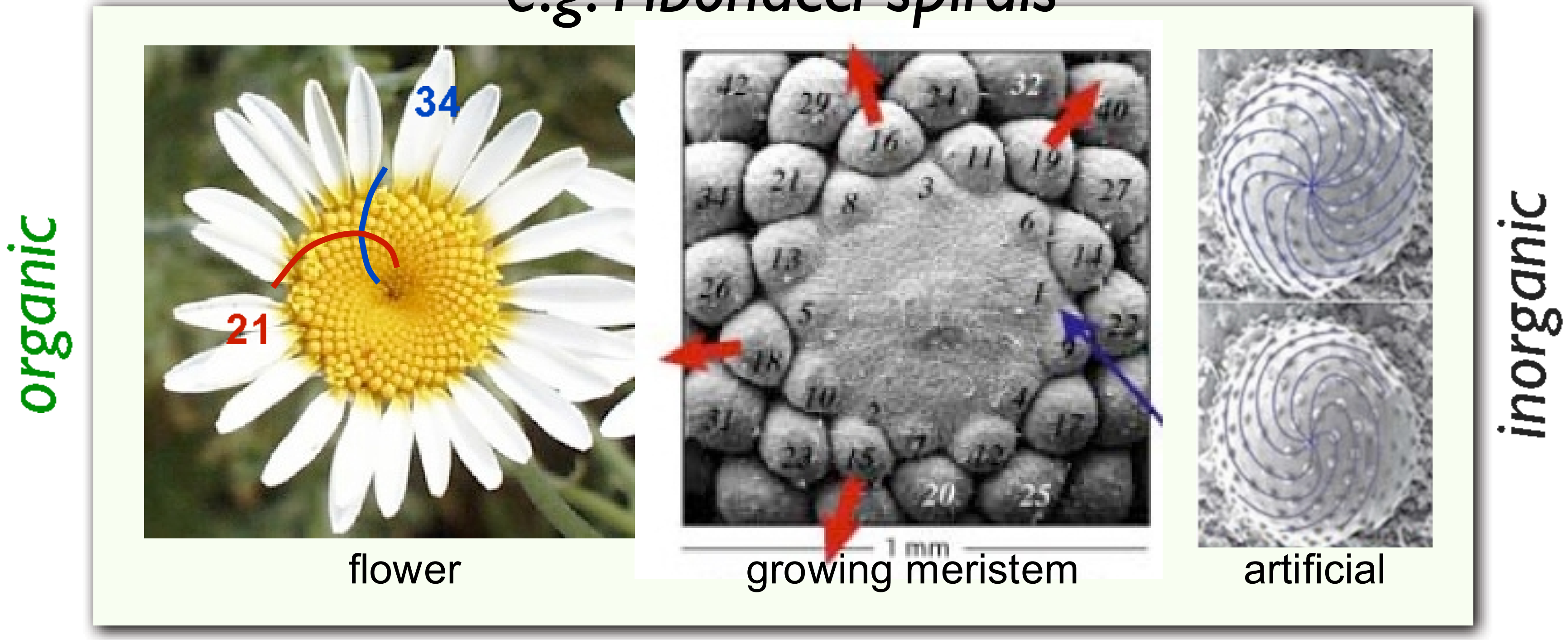
Laser: coherence amplifi-cation



Snow crystal growth

Taking advantage of self-organization

e.g. *Fibonacci spirals*

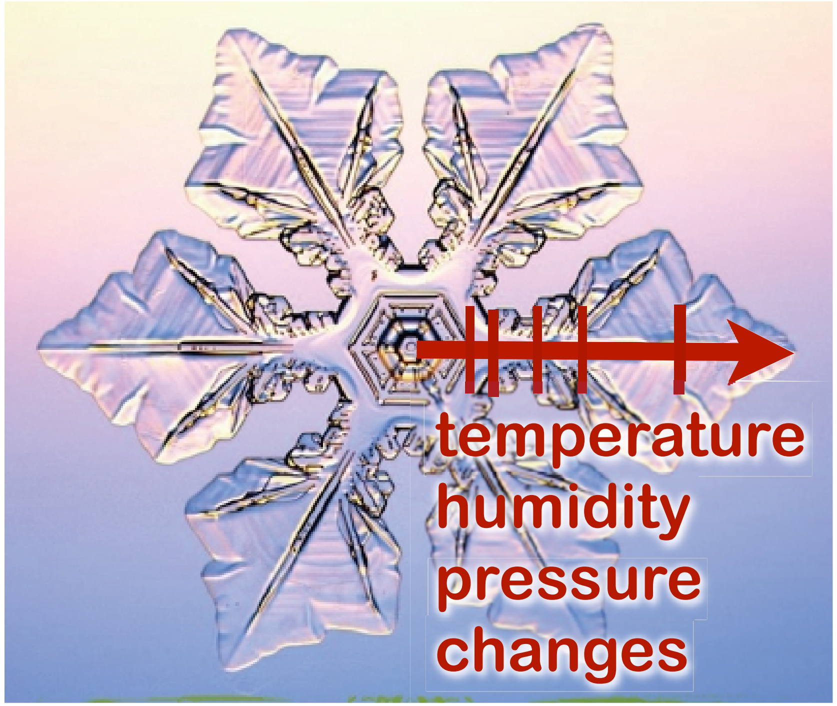


Natural selection "captures" self-organizing effects by preserving genetic constraints that regulate the conditions that favor their spontaneous formation.

Self-organization versus Life

- Physical systems self-organize because this more efficiently *eliminates the conditions that enable them*, i.e. organized to be more efficiently self-eliminating.
- For this reason self-organization (morphodynamics) cannot provide an adequate explanation for the dynamics of life, which must be specifically organized to prevent spontaneous self-destruction and maintain extrinsic support.
- *Paradox: Living systems must depend on morphodynamic processes to generate the constraints required to channel work that prevents spontaneous thermodynamic degradation, and yet must insure that these processes don't undermine the very conditions they depend on for persistence.*

Non-linear compounding of constraints



- Freezing preserves the constraints generated by morphodynamic processes allowing accumulation, historically capturing a representation of the effect of context on dynamics.
- Teleodynamic processes are higher-order nonlinear relationships between lower-order nonlinear processes

Organisms rely on self-organization for constraint generation yet invert its logic

- Organisms perform work to generate and maintain critical constraints against thermodynamic decay.
- Organisms depend on and utilize energetic and/or material gradients in their environment in order to perform work to *reconstitute the constraints* supporting their far-from-equilibrium dynamics.
- Organisms respond to *counter or compensate for the loss of critical gradients* necessary to maintain their synergistic integrity.
- Organisms evolve to *increase the indirectness of dissipation-path length* in order to extract more work.

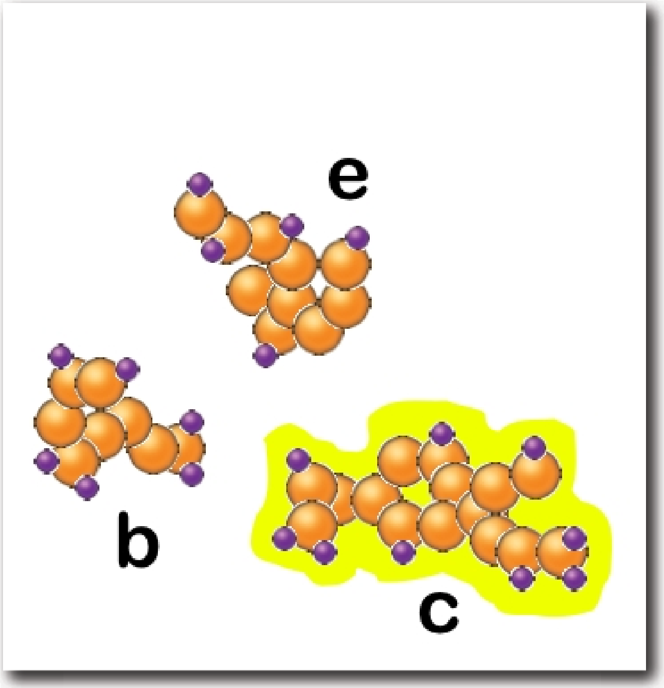
Kant: the self-forming power of organisms vs mechanism

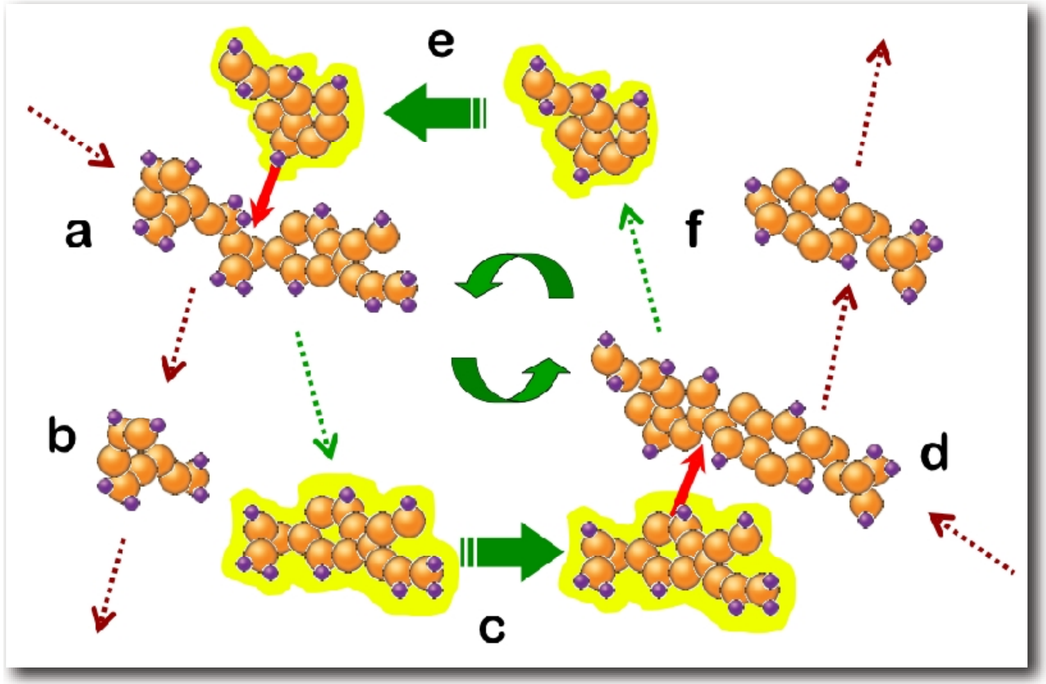
- "… a machine has solely motive power, whereas an organized being possesses inherent formative power, and such, moreover, as it can impart to material devoid of it — material which it organizes. This, therefore, is a self-propagating formative power …"
- "… in which, every part is reciprocally both end and means."

— Immanuel Kant, 1790

- *Is reciprocal component formation an end?*
- *Reciprocal co-production* ***resembles*** *teleology but there is nothing for the sake of which it's an end.*

Reciprocal catalysis (autocatalytic set)

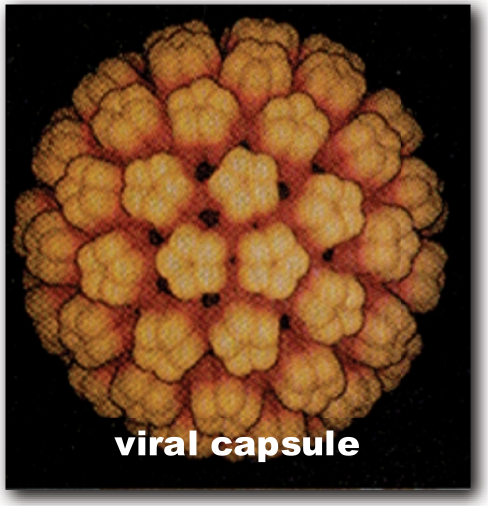


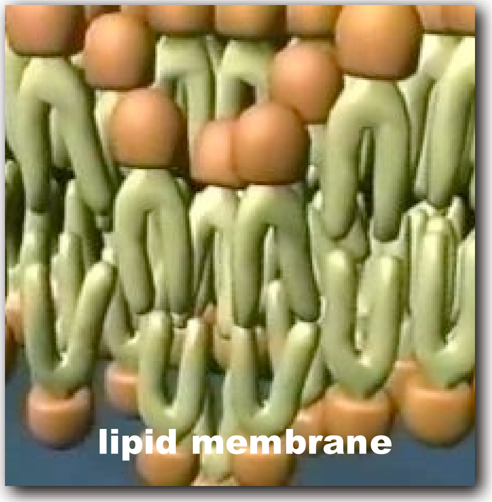


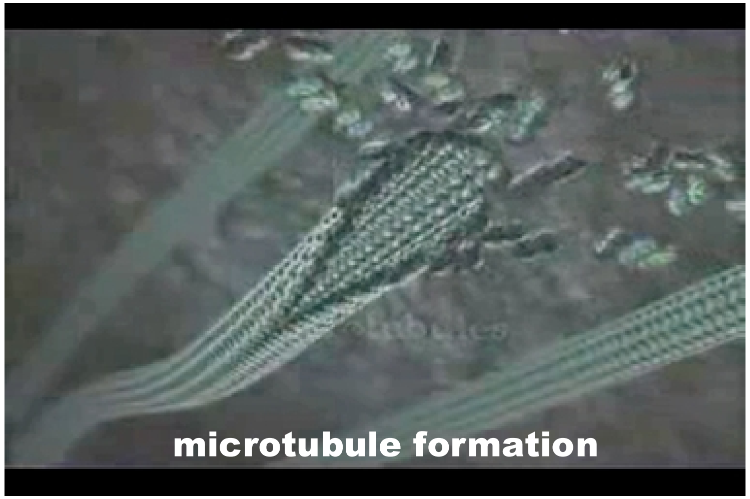
Lysis of molecule **a** into molecules **b** and **c** by catalyst **e** releases the energy of the broken covalent bonds

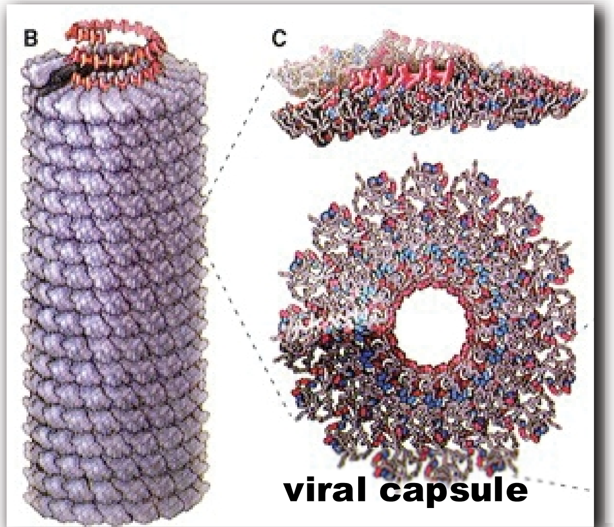
Reciprocal catalysis occurs when one catalytic reaction produces a product that catalyzes a second reaction which produces a product that catalyzes the first (and may involve multiple steps)

Self-assembly in viruses and cells









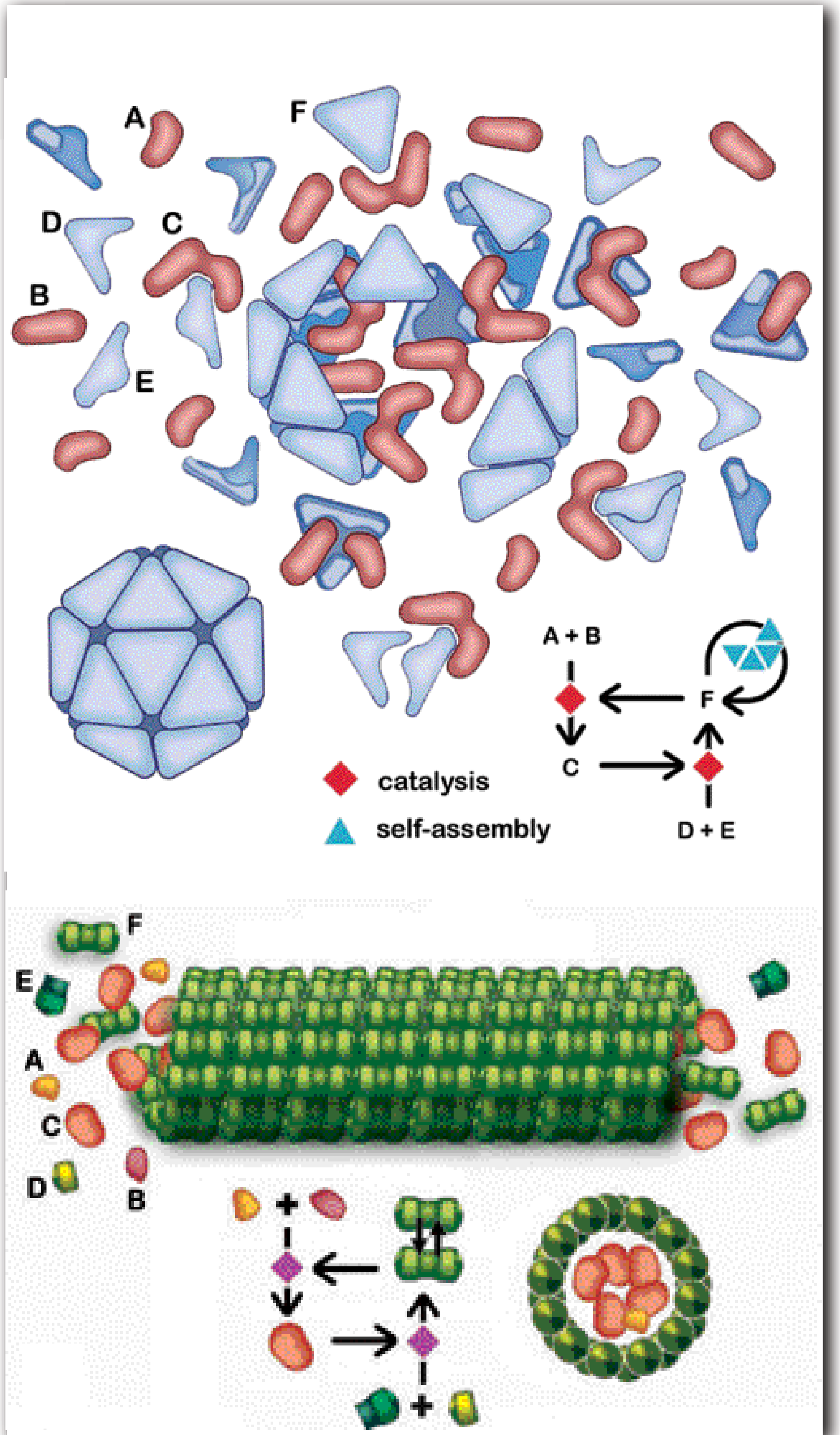
Self-assembly occurs when the complementary geometry of molecular surfaces facilitates spontaneous tesselation into sheets, polyhedrons, tubes, etc.

Two different morphodynamic processes that each produce the others' boundary constraints

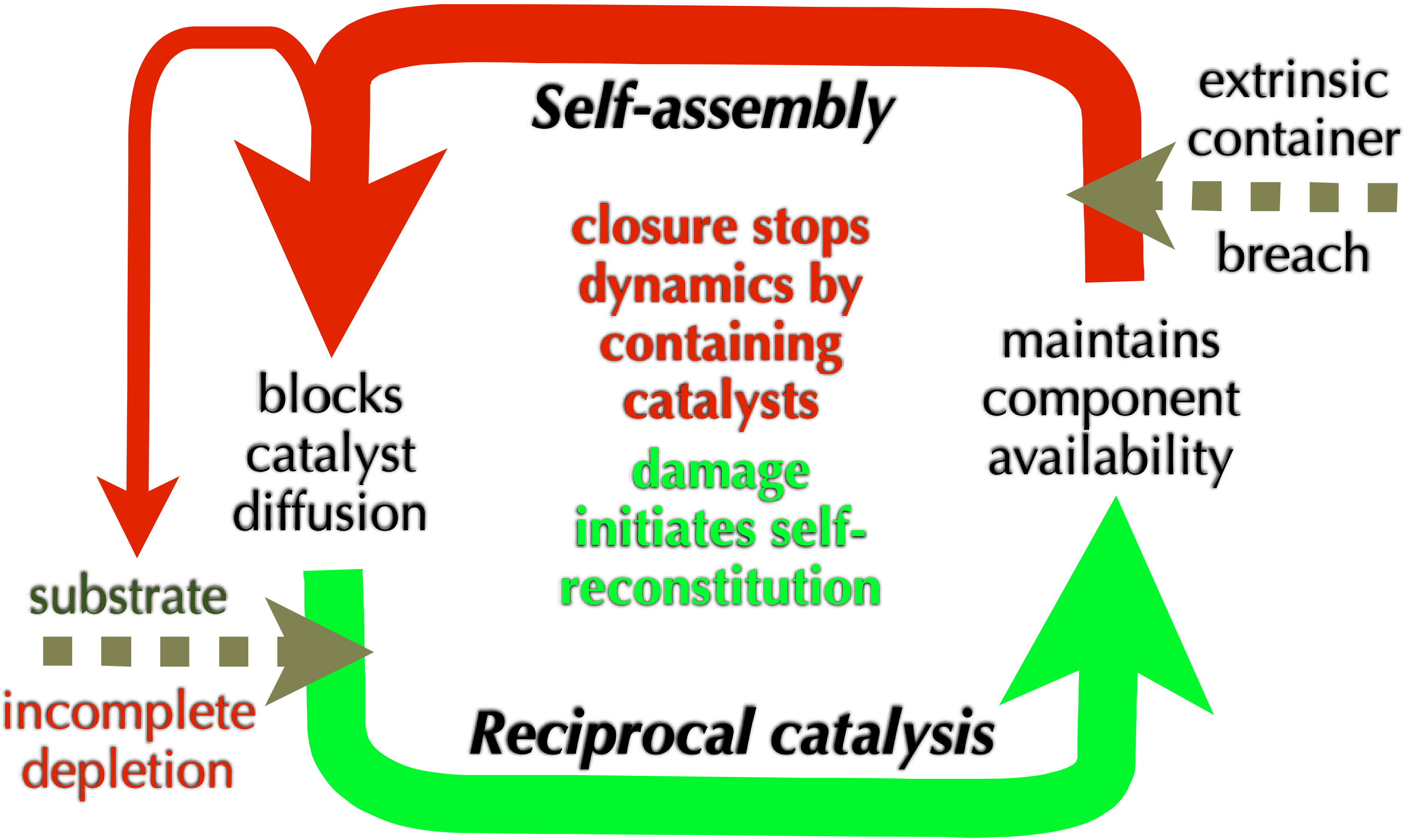
1. ***Autocatalysis*** (i.e. reciprocal catalysis)
   - Spontaneously self-amplifying catalytic chain-reaction with at least one energy-liberating reaction
   - Σ ***Produces*** high locally asymmetric concentrations of a msall number of molecular species
   - Δ ***Requires*** limited diffusion of interdependent catalysts
2. Enclosure ***self-assembly*** (i.e. formation of an enclosing surface by complementary bonding)
   - Spontaneous molecular tesselation due to stereochemical matching; molecular sheets
   - Δ ***Produces*** constraint on molecular diffusion
   - Σ ***Requires*** persistently high local concentrations of a single species of component molecule

Autogenic process

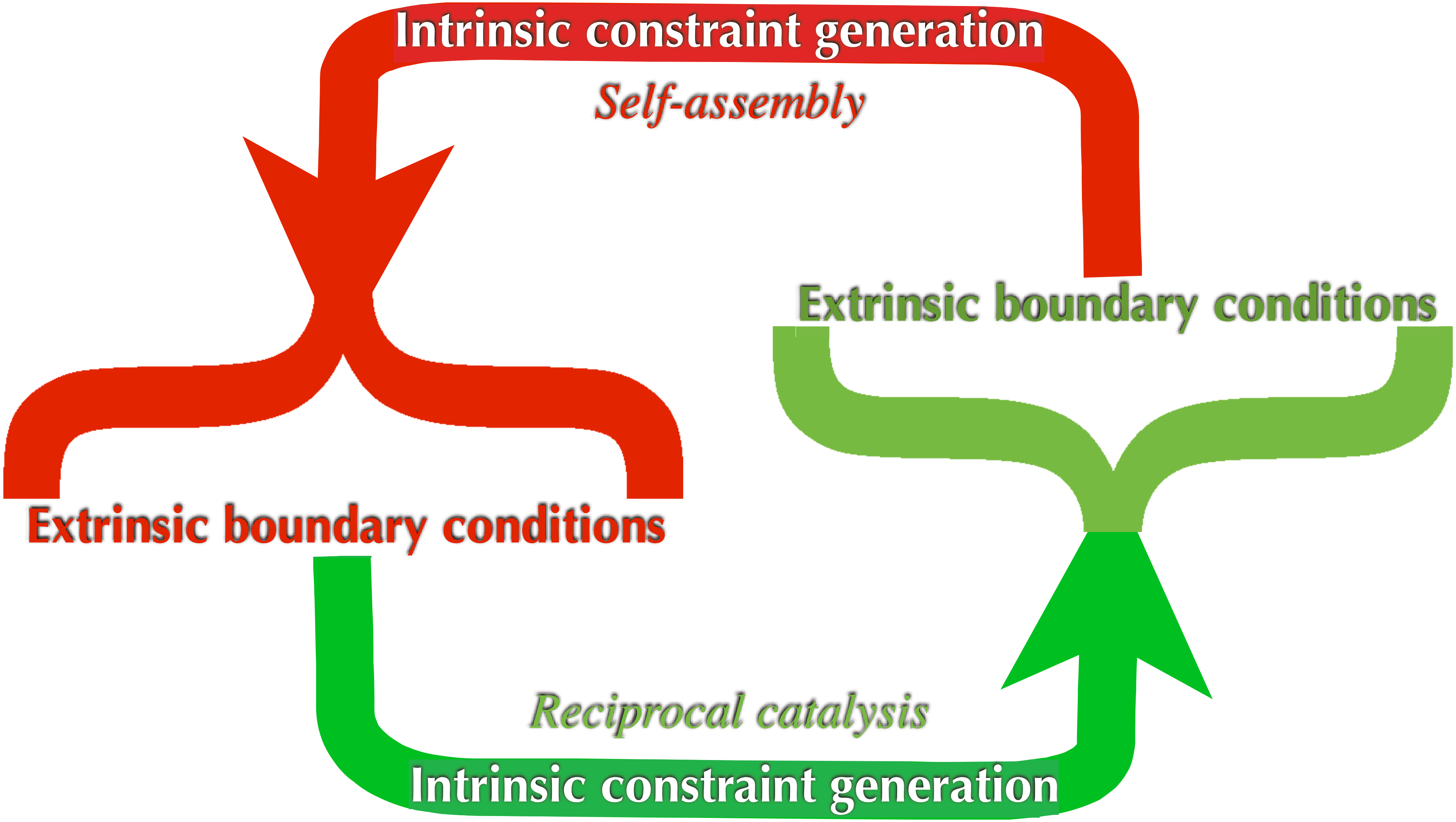
When one or more of the molecular products of a reciprocal catalytic cycle tends to self-assemble into a closed structure, spontaneous encapsulation of the ensemble of catalysts sufficient to recapitulate this process becomes highly probable.



The autogenic work cycle



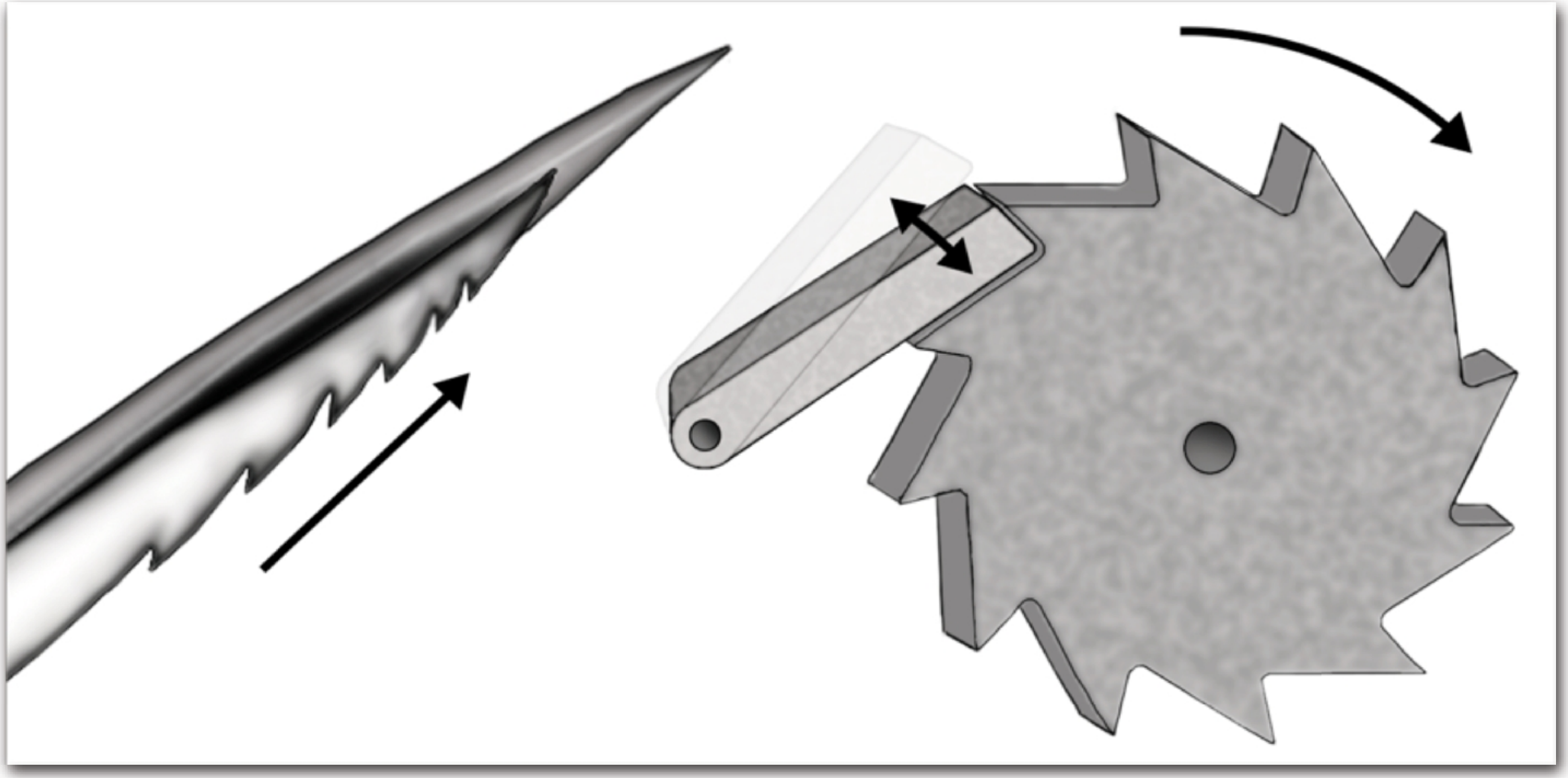
Co-dependent morphodynamic processes:
Extrinsic boundary constraints are provided reciprocally by intrinsic constraint generation



Teleodynamics creates "selves"

- Teleodynamics necessarily constitutes an individuated (i.e. closed and integrated) unit system because it is organized to reconstitute this same system-disposition if perturbed, whether from outside or from spontaneous internal thermodynamic decay.
- It is the maintenance of system integrity and synergy
- It is not vested in any particular component substrate or collection of substrates. It is *substrate-indifferent*.
- Self is defined by the disposition to initiate self-reconstituting dynamics when dissociated and to maintain the potential to reconstitute when stable.
- Self is thus a higher-order formal constraint on synergistic constraint-generating processes.

Autogenesis is a dynamical stochastic analogue to a mechanical ratchet



- Honey bee stinger
- Catch and gear ratchet
- Random disturbance + asymmetric constraint

Ratcheting constraint production

- Each of the two self-organizing processes are dissipative and subject to maximum entropy production
- Each is halted before the boundary conditions for each are exhausted
- Entropy production thus ceases and constraints are preserved before being dissipated.
- Entropy export is halted by the very process of entropy export, yet this constraint-preserving capacity is maintained.
- This synergy is what limits MEP and enables life.
- ***Evolution requires the generation, preservation, and compounding of new constraints.***

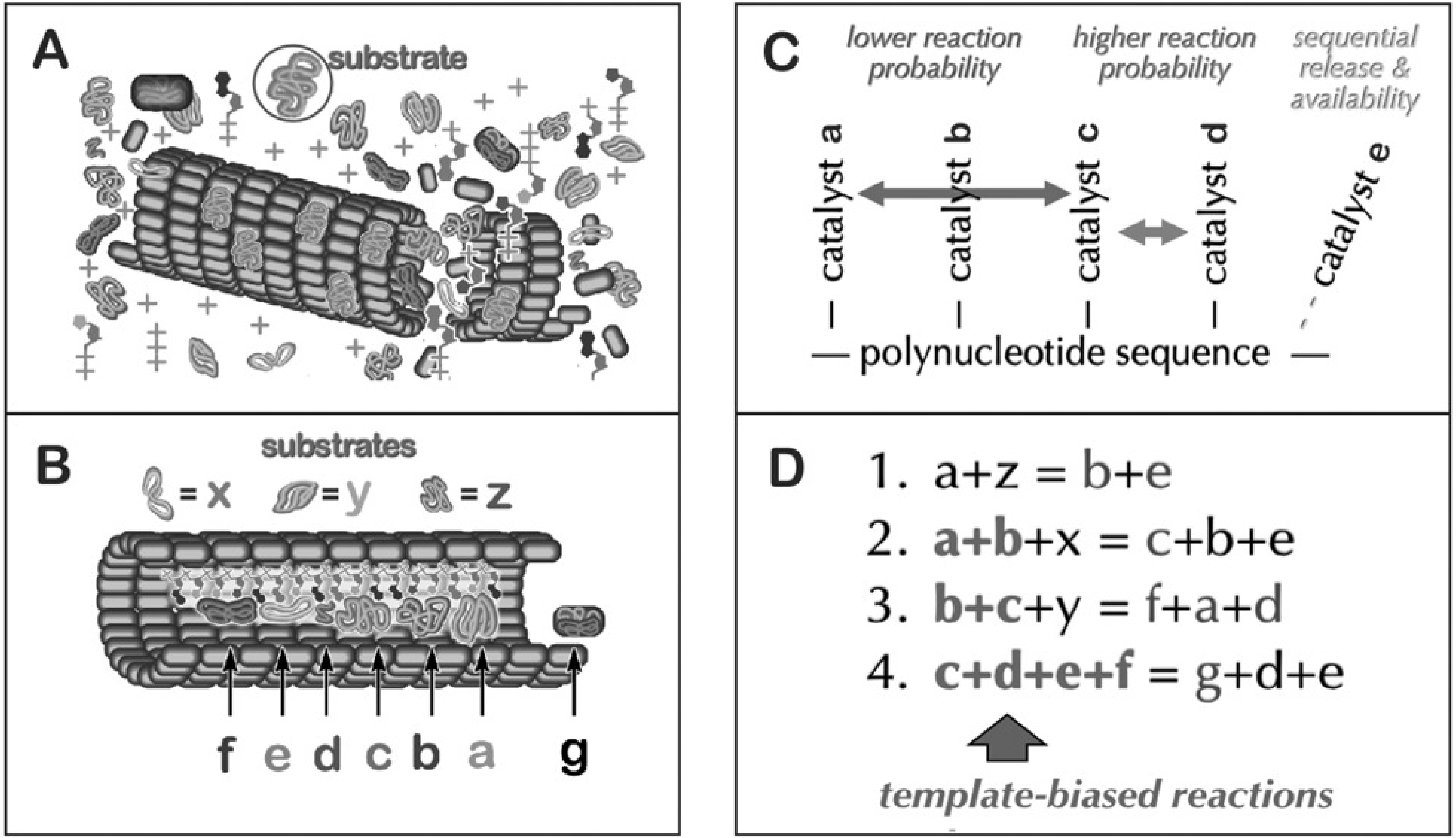
An autogenic equivalent of spontaneous mutation

- Shell enclosure will not only capture reciprocal catalysts in the local vicinity but also other molecules.
- Those that incidentally share catalytic inter-reactivity with autogen molecules will tend to be incorporated and replicated
- producing variant lineages in competition for related material and energetic resources of the environment

Limits to autogenic complexity

- A fundamental problem for systems employing reciprocal catalytic processes is the proliferation of competing side reactions.
- As the number of molecular species constituting an autogenic system increases the number of possible cross-reactions increases geometrically.
- This can both slow the rate of productive interactions and produce side reactions that remove critical components.
- Autogenic systems thus have limited evolvability

A. Regulated replication via substrate sensitive enclosure. B-D. Template-biased catalytic "network"



A part representing the whole of which it is a part

- Thus a molecular structure that is enmeshed in a teleodynamic system can increase or decrease the probability of system self-reconstitution, thereby potentially affecting preservation of that system and the specific molecular template structure.
- Such a molecule can literally re-present the topology of the dynamical network of interactions that optimally re-produces and maintains itself and its system.
- It is a part representing the whole by indirectly embodying the boundary conditions for its persistence along with the teleodynamics it stabilizes.