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Reparation as an emergent process in metabolic networks

Andrés Véjar · Iván Gómez-Castaño

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Abstract In biology, one of the most challenging problems is how the emergence of self-organization and operational closure are maintained through time. In this topic, phenomena like regulation, replication and reparation have to be defined in order to get a concept of self-organization. Up to now, reparation in metabolic networks has a non trivial description and many efforts have been made to investigate related concepts as closure existence or system dynamics. We propose a model where the coexistence of intermittent coupled dynamical systems allows the emergence of global reparation as a property of the whole network and, also, it is needed to maintain the normal function of the individuality in time.

Keywords self-repair · catalysis · self-organization · (M, R) -systems.

1 Introduction

Different proposals in self-organization have as central idea the operation of a catalytic closure to start the process of differentiation from the environment [10, 9, 7, 12]. For this, the basic concept of two basic molecules, one catalyzing the other to produce a new one, is one of the basic requirements to start an operational closure. All these types of models try to solve the problem of how catalytic closures are able

to maintain it in time with an adequate quantity of catalyst molecules. Nonetheless, self-repairing of catalytic molecules in a chain of reactions remains an unsolved issue in theoretical biology.

A very precise molecular description of the pathways involved in self-repair at biological sciences is deeply described. Nonetheless, such types of specialized mechanism belong to a more complicated infrastructure that, at the beginning of life, with a limited number of species and functions, could be not possible to obtain [8]. For this reason, simpler and more efficient mechanisms of self-repair had to emerge in the mutual interaction of simple catalytic species [13]. A classical example of catalysis in biological systems are the enzymes, molecules encoded in highly conserved DNA or RNA templates that have a great importance for the maintenance of catalytic closures at the beginning of life, as well as in present times [11]. In this communication, we propose a model where the self-repairing catalytic properties in a cell can emerge as the result of interactions in the network. Even that enzymes production based on the transcription of DNA templates is very efficient, it seems that complicated multi-steps processes at the beginning of life are more difficult to obtain. By this phenomena, maybe the emergence of the first mechanisms of reparation (independent from DNA) can be due to this emergent process, a more simple and dynamic one.

2 Metabolic Repair

In Rosen's (M, R) -systems researches [1, 4, 6, 5, 3], they generally try to solve the closure of an autonomous system by means of a switching route between mapping of mappings, but no time scales are considered. Some class of instantaneous reparation is needed by this type of modeling, and no satisfactory solutions can be given, because only the exis-

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tence of global mappings switching functions and inverses are a difficult mathematical problem [6]. The complexity of the (M, R) -systems can be analyzed with hyperset theory [2], to avoid the computational modeling of the autonomy in life systems.

3 Modeling

Be the process $a \xrightarrow{f} b$, where f is the catalizer of this reaction. If f has a lifespan, it is conditioned by its own degradation through time. When f is degrading, the output b is also gradually corrupted. If in an instant t the elements of a system are a and f , this state is expressed by $\{a, f\}_t$. If the reaction time is p , a is joined with f_t in an instant t to generate b_{f_t} , then the *history* of the system is $\{a, f\}_t, \{f_{t+p}, b_{f_t}\}_{t+p}$.

If $f_i, n < t < m$, is in a normal production state (not completely degraded), with n the starting production time, and m the complete degradation time, then the process can be described for the diagram:

$$\begin{array}{c} \downarrow a \uparrow b_{f_i} \\ f_n \dots f_t \quad f_{t+p} \dots f_m \end{array}$$

For simplicity, if f has only two states N (normal) and D (degraded), the process has the followed transitions:

$$\begin{array}{l} \text{normal} \quad : \{a, f_N\}_t \longrightarrow \{f_D, b\}_{t+p} \\ \text{degraded} : \{a, f_D\}_t \longrightarrow \{a, f_D\}_{T>t} \end{array}$$

In order to maintain the process $a \xrightarrow{f} b$, for long time, another intermitent transition to repair f is needed, $\{f_D, b\}_t \rightarrow \{b, f_N\}_{t+r}$, with process time r , then a part in the *history* of the process could be:

$$\{a, f_N\}_t, \{f_D, b\}_{t+p}, \{b, f_N\}_{t+p+r}$$

The intermitent process is showed in Fig. 1, and also in a state diagram in Fig. 2.

More precisely, in the modeling, the self-repair system is an intermitent coupled dynamical system that evolves at different time-scales, specially the production time-scale, the repair time-scale, and the parameter evolution time-scale.

4 Conclusions

In this work we discuss the concept of self-reparation in living systems, modeling the production and reparation of different coupled processes that coexist in different time-scales. The feedback between systems in the network is maintained in intermitent oscillations. The study of long-term dynamics, is essential to show the self-reparation as an emergent behavior, and in our model, the self-reparation is vanished if we analyze only the short-term behavior.

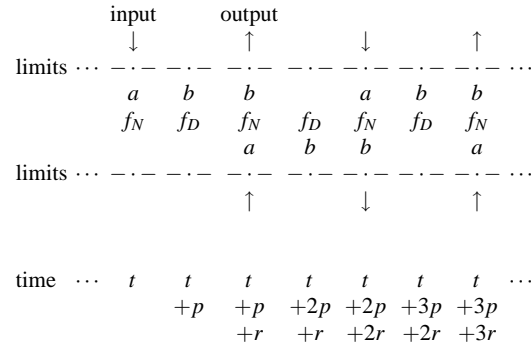


Fig. 1 Diagram of evolution for the intermitent oscillatory processes of transformation and reparation

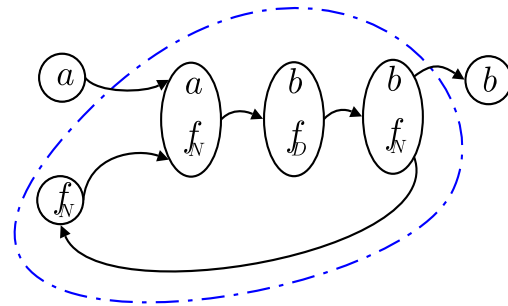


Fig. 2 State diagram of a process $a \xrightarrow{f} b$.

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