Modeling Adaptive Multi-Agent Systems Inspired by Developmental Biology

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Organism

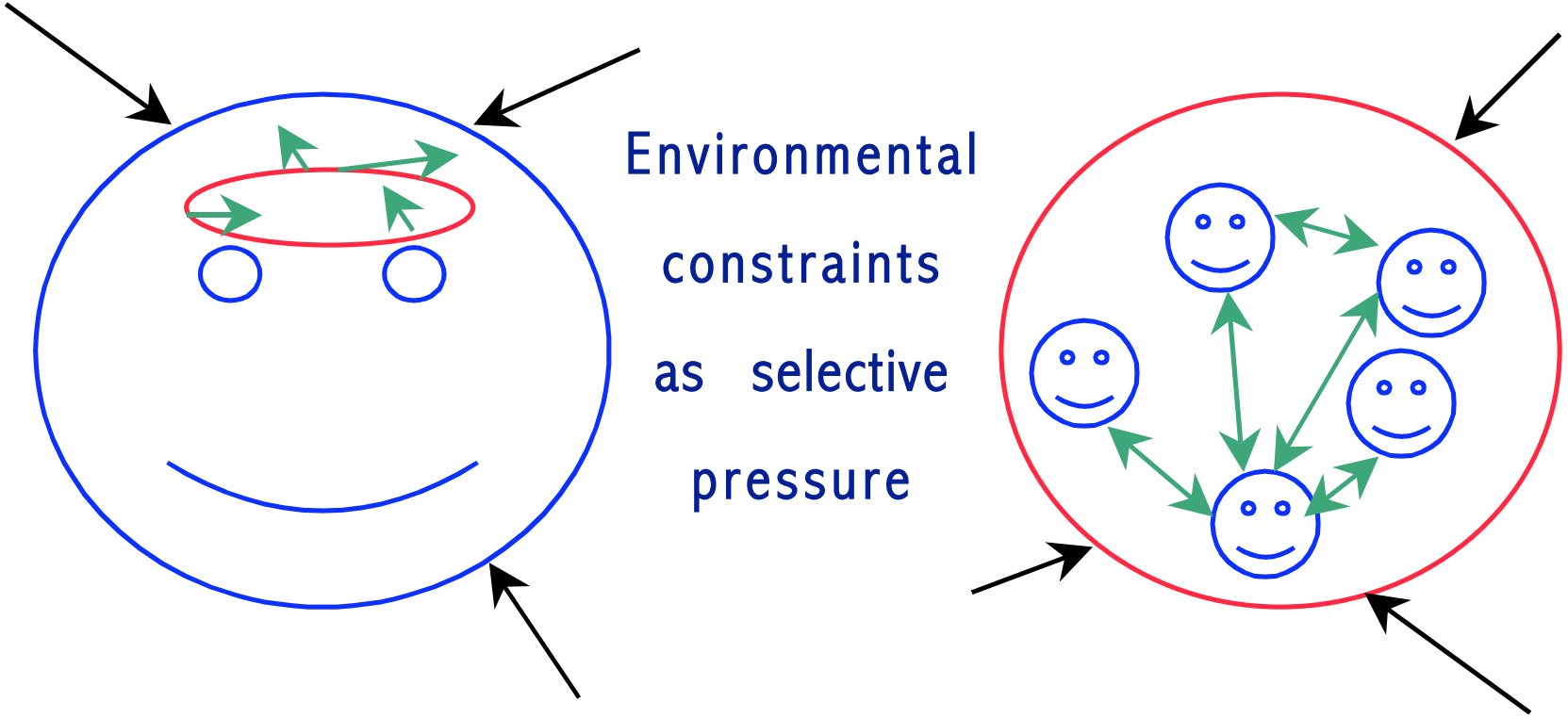
- Adaptation of the whole system to its environment
- Embodiment as a coupling process between a physical body and a cognitive structure, relying on the situatedness of the system
- Emergence of a collective behavior
- Development of the system = ontogenetic process

Ecosystem

- Adaptation of each agent to its own environment
- Collective learning process relying on the situatedness of the agents in the system
- Emergence of an organization in the system

- Evolution of the agents in the system = phylogenetic process

Duality induced by the metaphors



Environmental constraints as selective pressure

Organism ⟺ **Ecosystem**

that develops (composed of agents)

Composed of agents that evolve

Purpose of our research

- Phylogenetic and ontogenetic processes = same phenomenon at different scales

- Proposal for embodiment = the organization process of situated agents in the system

- Purpose = studying the evolutionary process that produces the organization, rather than the embodiment directly
  = how to have agents behaviors evolve in a situated system ? («□Ethogenetics□»)

«Ethogenetics» is our approach to the design

of evolvable agent behaviors in a situated system

It implies the use of a structure for producing the behaviors of the agents, with the following requirements :

(1) It should allow for agents behaviors to be of any complexity

(2) It should allow cumulative adaptation in order to allow (3)

(3) It should be evolvable through a «blind» evolutionary process (e.g. Darwinian selection) which is a kind of unsupervised learning

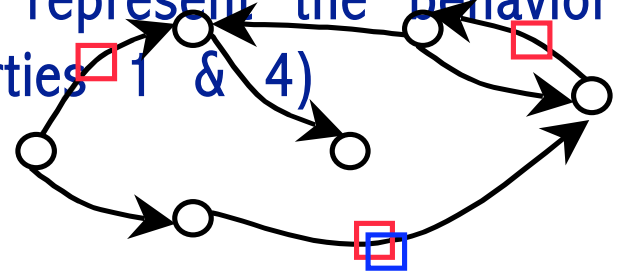
(4) It should be understandable and manipulable directly by a human designer (for bootstraping, observation, modifications...)

The ATNoSFERES Model

Existing evolutionary approaches (e.g. Genetic Algorithms, Genetic Programming...) do not meet the 4 requirements simultaneously !

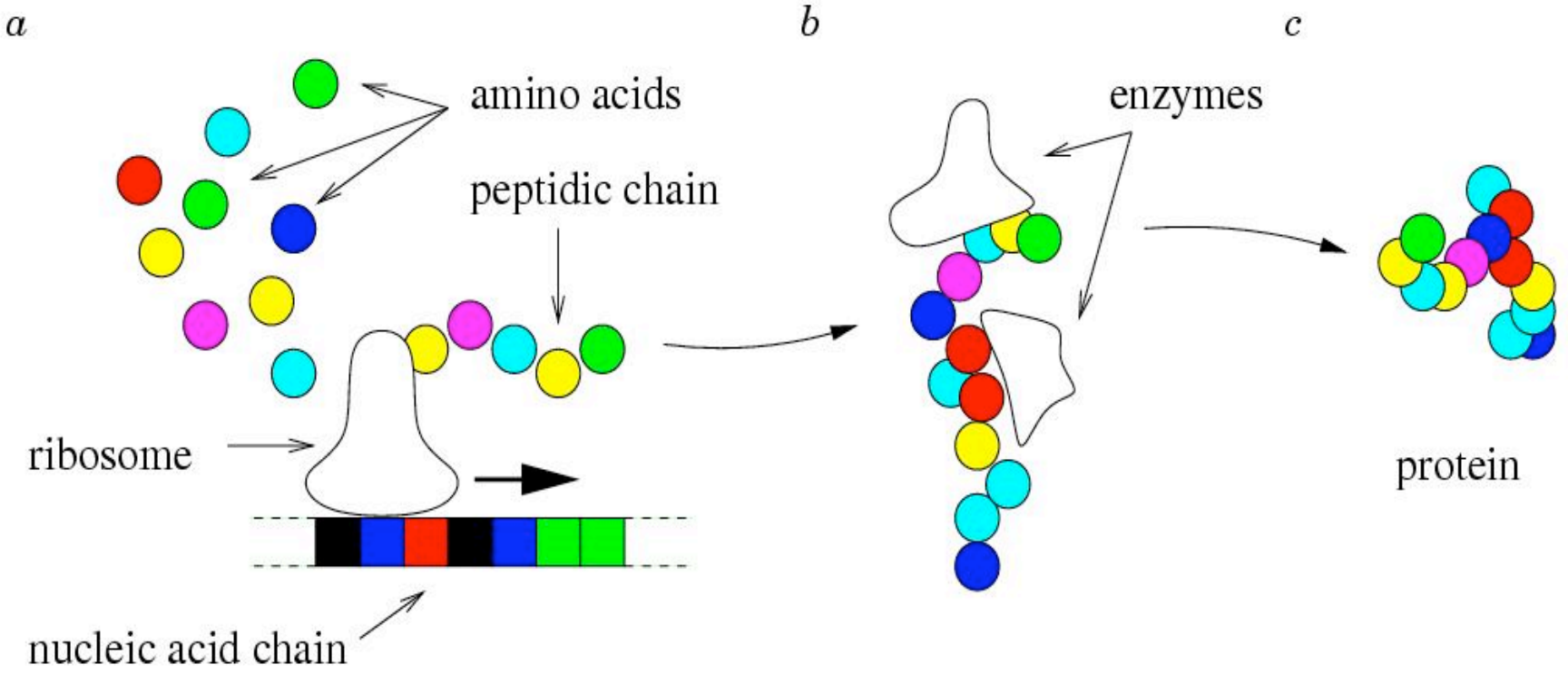
The model we propose as an illustration of Ethogenetics is based on:

- a non-deterministic automaton to represent the behavior of any agent (ATN Graph; ensures properties 1 & 4)

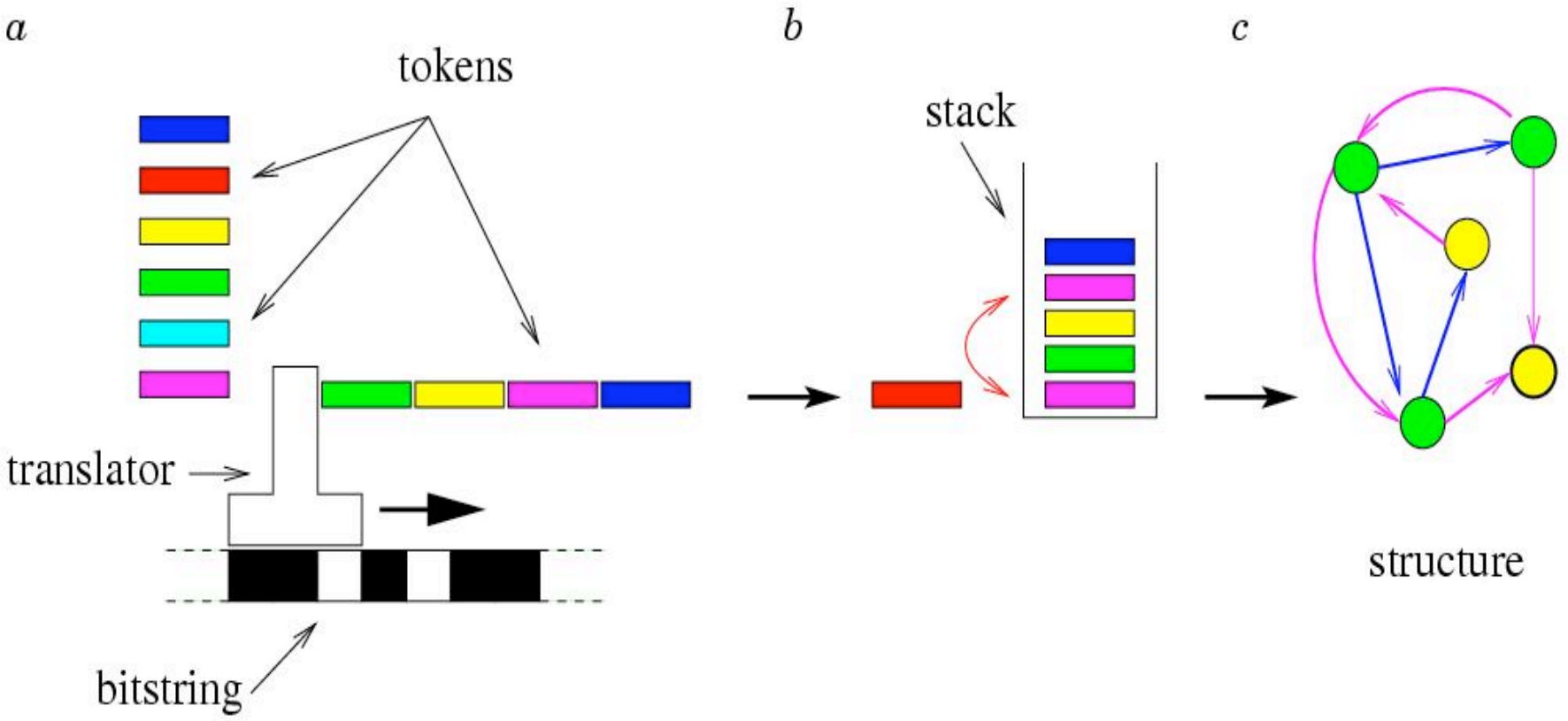


- a bitstring as hereditary substratum (gene) for building this automaton
- a stack-based gene expression process (to ensure properties 2 &

Biological Gene Expression



Stack-based Gene Expression



Properties of the ATNoSFERES Model

- No specific hypothesis regarding the cognitive abilities of the agents
- Any genotype (bitstring) produces a consistent automaton
- Continuity between genotype (bitstring) and phenotype (ATN)
- Completeness of the ATN-building language

- Validation of the model through simple problems
- Ongoing experiments on predators/preys issues

Conclusions & Perspectives

- The ecosystem approach to adaptive MAS might be an easier approach to embodiment than the organism viewpoint

- Next experiments: formation-based navigation in a group of robots (part of the MICRobES Project: http://miriad.lip6.fr/microbes/)

- Additional research on evolvability