

Evolutionary and Adaptive Robotics: Behaviour and Cognition as Complex Adaptive Systems

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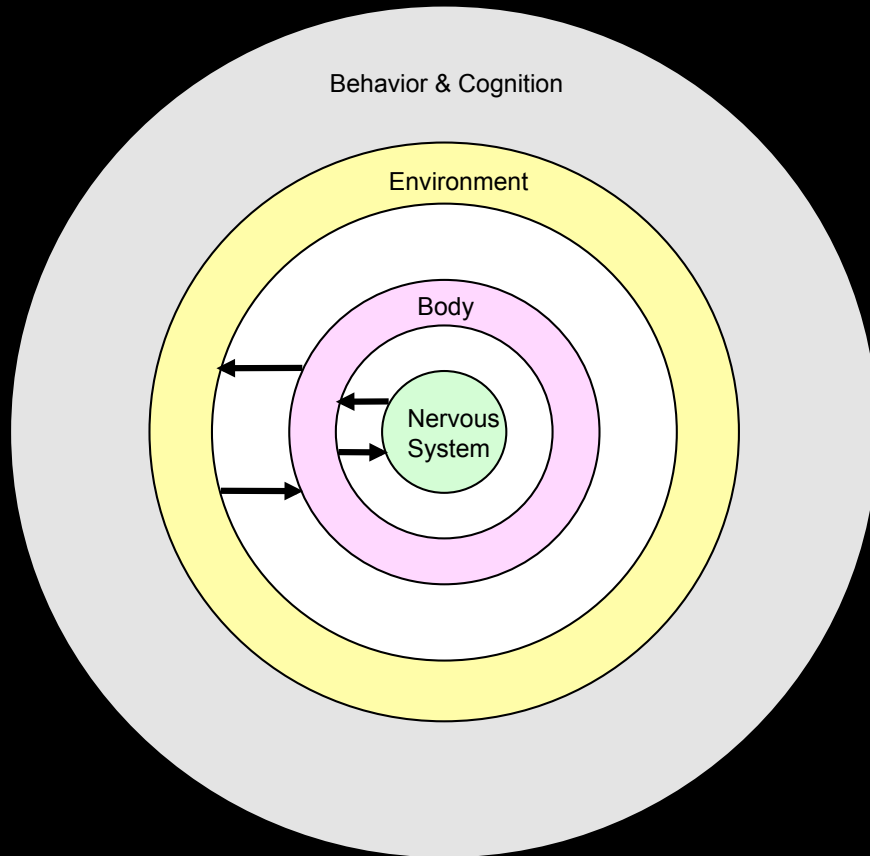
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Outline

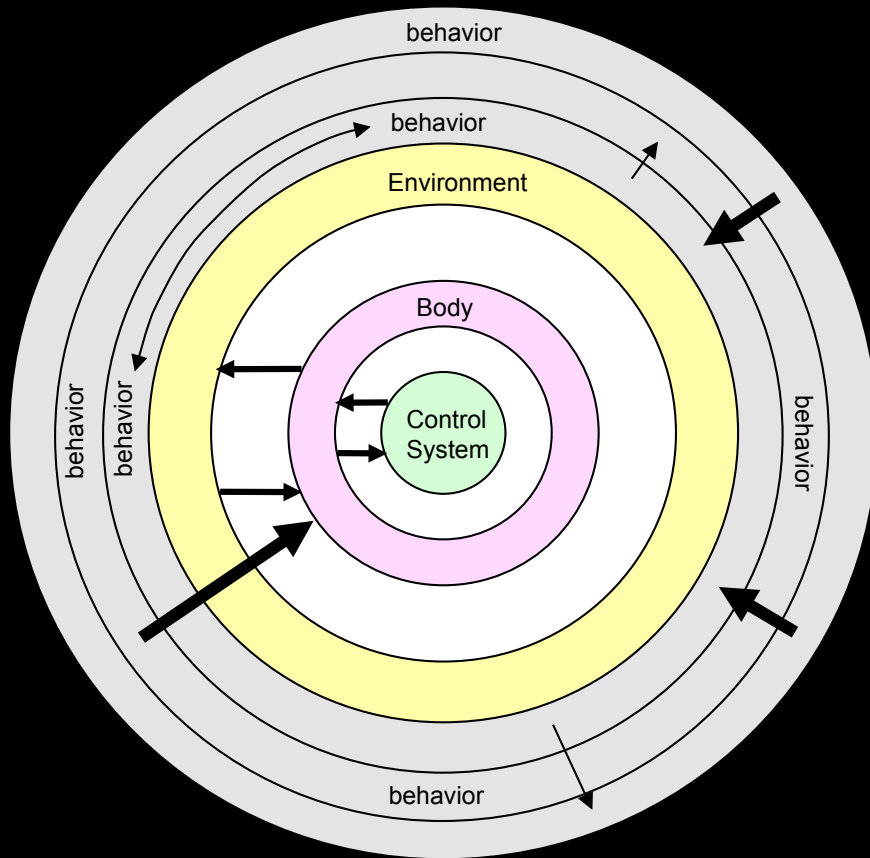
1. Behaviour and Cognition as Complex Adaptive Systems
2. Adaptive Approaches to Robotics
3. Examples illustrating the emergent nature of behaviors and cognition
4. Examples illustrating the multi-level and multi-scale nature of behavior

Behavior and Cognition as Dynamical Systems



Behaviour and cognition are dynamical processes that extend over time and result from a large number of robot/environmental interactions occurring at a fast time rate between the robot's control system, body, and the environment.

Behavior and Cognition as Complex Multi-Level and Multi-Scale Dynamical Systems



(i) The interactions between lower-level processes (that extend for a limited time duration) give rise to higher-level processes (that extend for longer time spans)

(ii) higher-level processes later affect the lower-level processes from which they originate

Implications of the Complex Dynamical System Nature of Behavior and Cognition

Emergence: Possibility to exploit properties that emerge from the interactions which leads to **compact** and **integrated** solutions

Adaptability: Possibility to progressively improve and expand agents' behavioral and cognitive skills through progressive variations and behaviour re-use.

Embodiment and Situatedness

Embodiment: Suitability of the body to exploit the interaction with the environment



[Collins, 2000']

Situatedness: Suitability of the control system to exploit the interaction with the environment

coordinated motion

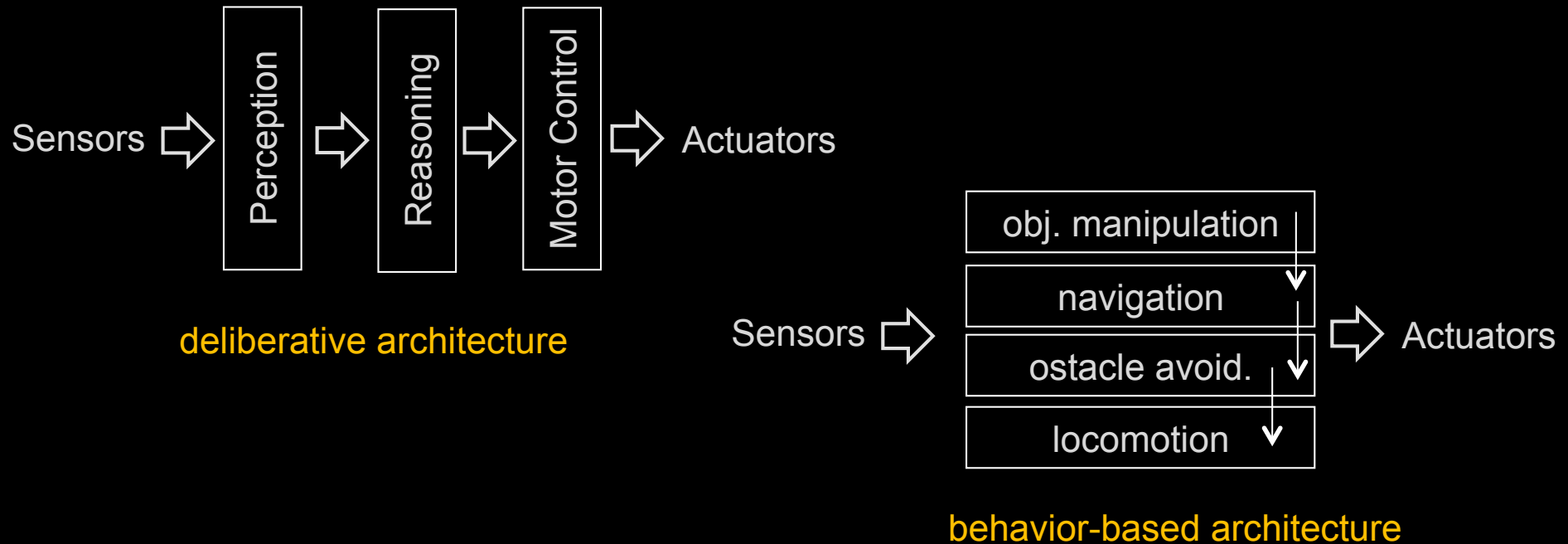
[Baldassarre, Trianni, Nolfi 2006']



[Tuci, Ferrauto, Nolfi 2010']

In embodied and situated systems, the characteristics of the agents are strongly integrated with the characteristics of the environment and of the task

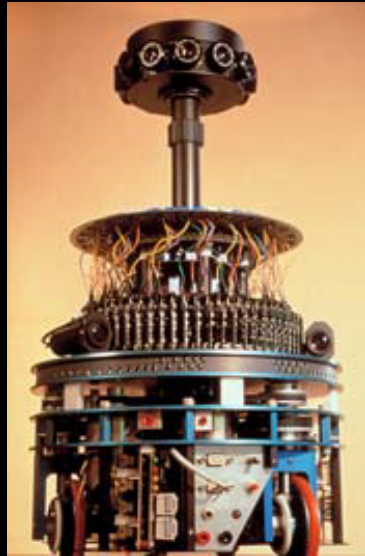
Design Methods



Problem 1: These design methods based on a set of relatively independent layers/modules playing different functionalities tend to minimize the effect of the interactions

Problem 2: The effect of the interaction can be minimized but not eliminated. The human designer therefore needs to face the problem caused by unexpected emerging properties that can hardly be predicted or deduced by the characteristics of the interacting elements

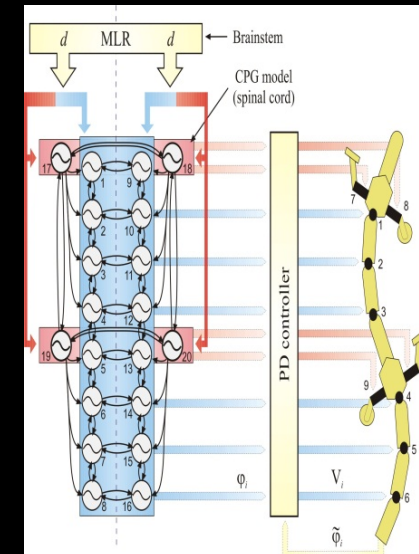
Bio-Inspired Methods



Franceschini et al. 1992



Ijspeert et al. 2007



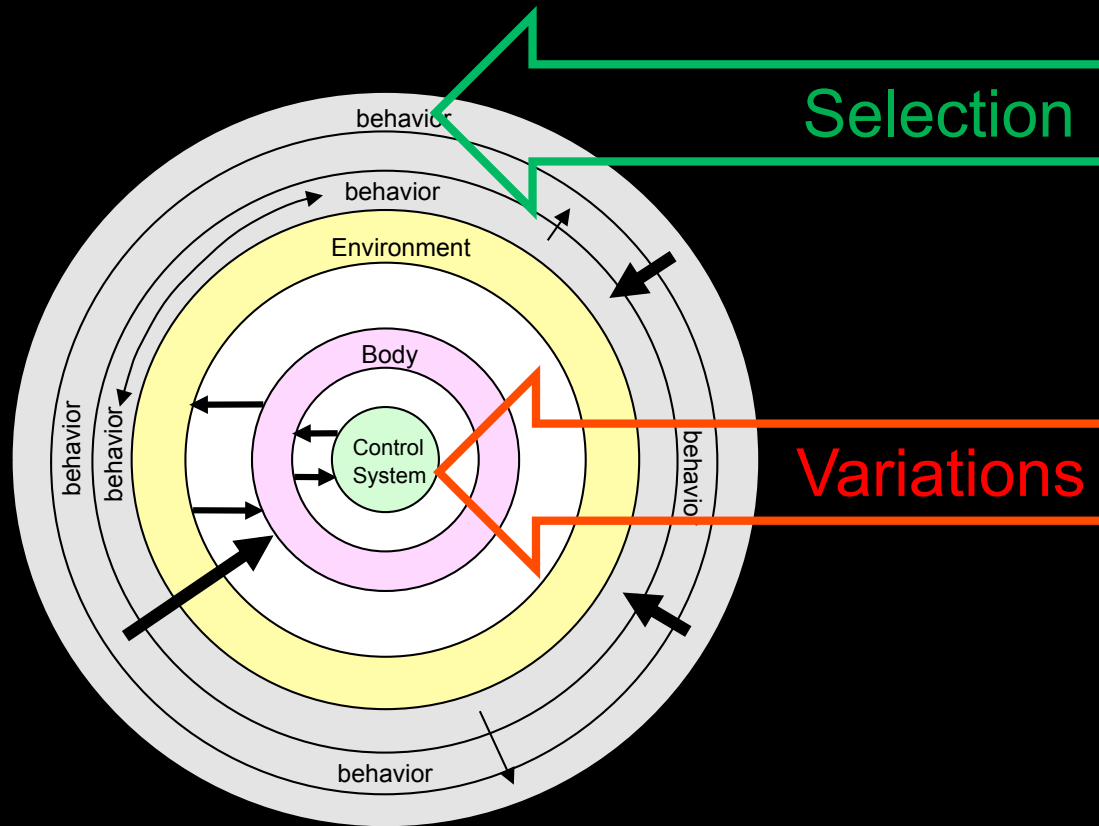
This method allows to capitalize on embodied and situated solutions discovered by natural evolution but can be applied only to domains/solutions for which we have a detailed understanding

Adaptive Methods

Allowing the robots themselves to develop their skills autonomously while they are situated in their environment through a phylogenetic and/or ontogenetic adaptive processes homologous to natural evolution and/or learning

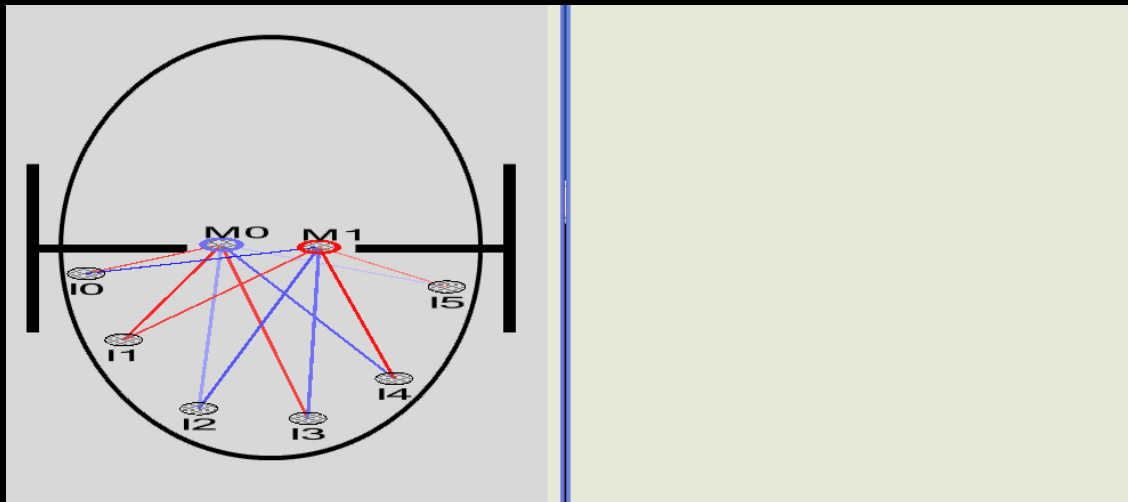
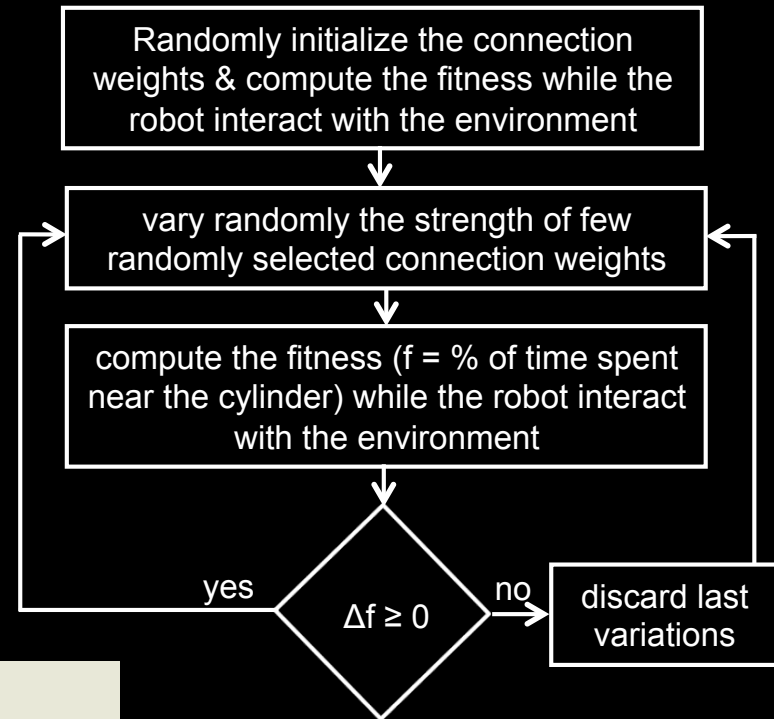
Evolutionary methods, inspired by the way in which natural organisms adapt phylogenetically, **developmental** methods, inspired by the way in which natural organism change ontogenetically, and **combination** of the two.

Fundamental property 1: Variation and selection operate at the lowest and highest levels of organization



Selection operates on a process that result from the agent/environmental interaction

Finding and Remaining Close to a Target Object



Fundamental property 2: Evolution operates on a population of individuals

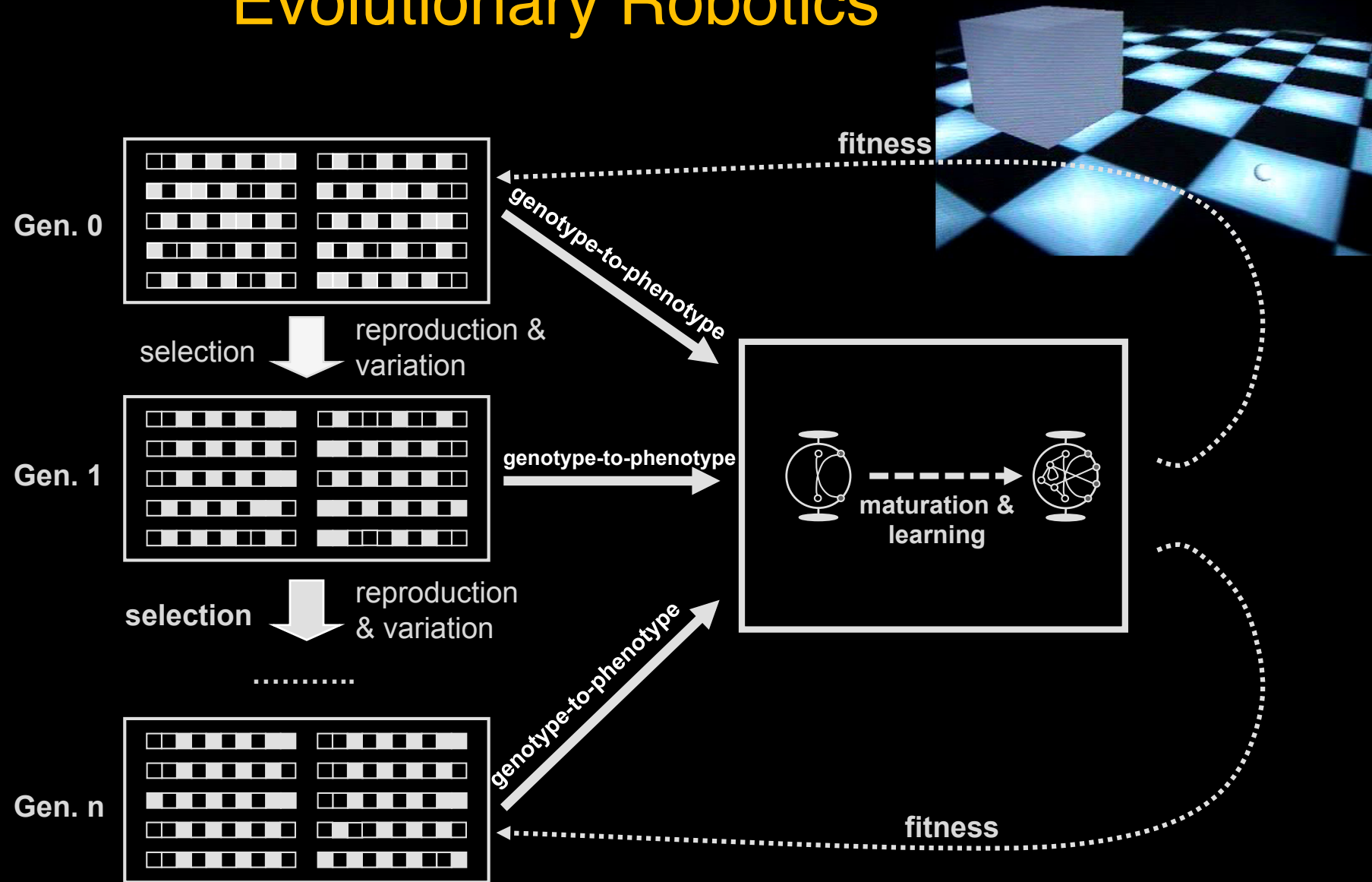
To speed-up the adaptive process (parallel search, recombination)

To increase the robustness of the adaptive process

Enable the synthesis of social behavior

Evolutionary Robotics

[Bongard & Pfeifer, 2001]



Evolution of coordinated/cooperative behavior

