Learning drives the accumulation of adaptive complexity in simulated evolution

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Developmental plasticity and particularly learning enable organisms to cope with new environmental challenges. But if learning is costly, the same behavior could evolve through Darwinian modifications of development that substitute for the role of learning in the acquisition of that behavior, a hypothesis known as the Baldwin effect. Computer simulations have confirmed that learning accelerates evolutionary adaptation to a single problem posed by the environment. What has not been shown, however, is the way in which the driving force of learning can generate ever greater complexity in organization of evolved behavior, the one that has very small chance to appear in one step in the course of evolution. Here we report such consequences of the role of learning using a model fitted with sequentially appended adaptive systems.

A central component of our approach is that of a functional system. It asserts that each adaptive behavior is executed by a distributed system of phenotypic elements that cooperate towards organism's fitness in this particular task. Novel challenges lead to generation of new adaptive functional systems that can be added to the existing ones either by evolution of development or by learning. This allows the establishment of elaborate behavior patterns and results in increased complexity of organisms at the systems level. Selection assesses organisms by the adaptiveness of their functional systems and the more functions the individual possesses, the more competitive we assume it is. The greater complexity in our model implies more extensive repertoire of behaviors supported by greater amounts of equipment for monitoring and coping with the environment. From a biological standpoint an organism with the higher functional complexity will be better able to deal with a variety of challenges from the environment and therefore will be more likely to survive. If considered from the perspective of a single ecological challenge requiring just one functional system our model is similar to a classical single-peaked landscape simulation by Hinton & Nowlan. However, the main highlight of the model is its operation in a complex evolutionary landscape similar to the "Royal Staircase" fitness function of van Nimwegen & Crutchfield, which allowed us to examine coordinated evolution of multiple functional systems under the impact of learning and developmental plasticity.

The results of simulations demonstrate that ability to learn dramatically accelerates the evolutionary accumulation of adaptive systems in model organisms with relatively low rates of mutation. The growth of complexity is mediated through a process of allelic substitutions that simulate emergence of evolutionary predispositions for learning of certain behaviors and simultaneously release organisms capacities for acquisition of next tasks. The effect of learning on evolutionary growth of complexity is even greater when the number of elements required for adaptive system is increased. These results suggest that as the difficulty of challenges from the environment become greater, so learning exerts an ever more powerful role in meeting those challenges and in opening up new avenues for subsequent genetic evolution of complex adaptations.