
ALife researchers have typically interpreted the Baldwin effect (BE) [2, 3] as a two-step evolution of the genetic acquisition of a learned trait without the Lamarckian mechanism: Individuals that have successfully adapted their own trait to the environment through their lifetime learning processes occupy the population (first step), and then the evolutionary path finds the innate trait that can replace the learned trait (second step) because of the cost of learning [17]. I think that this definition stemmed in part from the introduction of Hinton and Nowlan's pioneering work [6] on the BE by Maynard-Smith in Nature [8]. However, what we first learn from this book is that the BE has been redefined several times and diversely interpreted in its more than 100-year history. This book is a collection of essays on this effect and related concepts, written by participants in an interdisciplinary conference on the emergence of mind and by several invited authors. It includes the history of the BE, its significance in language evolution or developmental biology, and its relationship to the evolution of consciousness or mind as an ultimate form of phenotypic plasticity. Recently, the BE and the role of phenotypic plasticity in evolution have been drawing much attention in evolutionary developmental biology; many experimental results on this effect have been reported [4, 13, 20]. Here, I summarize the topics in each chapter and then make several comments on what needs to be added, together with implications for further research on the BE in the ALife field.

David J. Depew, one of the editors of this book, reviewed various versions of the BE defined by Baldwin himself, by the framers of the modern synthesis, and by the contemporary boosters of the BE such as Dennett and Deacon (Chapter 1). For example, according to Depew, natural selection is an indiscriminate force (rather than a creative force) that kills individuals before their reproduction (thus, adaptive learning keeps the individuals alive and determines evolution by securing genetic variations) in Baldwin's original scenario of “organic selection” [2, 3]. On the other hand, the BE is merely a special case of Waddington's genetic assimilation [18] for G. G. Simpson [14], who named the term “the Baldwin effect”; however, he was skeptical about its significance. Depew states that, if the history of the BE is any guide, we should be cautious about dismissing these hypotheses just because they do not fit with existing interpretive schemes. Although Stephen M. Downes and Peter Godfrey-Smith are skeptical about the BE, they discuss the differences between these versions from several viewpoints. Downes classifies them by focusing on what kind of traits are considered and what kind of outcomes will be brought about as a result of the BE (Chapter 2). Godfrey-Smith compares the significance of several mechanisms that enable the ontogenetic adaptation (first step) to affect the acquisition of the innate trait (second step) among these versions (Chapter 3). He points out that the existence of similarity relations between genotypes can facilitate the genetic acquisition of the learned trait, but the niche construction induced by the ontogenetic adaptation is a more significant mechanism for the evolution of a novel trait that differs from the one previously acquired through the learning process.

One of the controversial issues relating to the BE is language evolution, which includes both the cultural evolution of language and the evolution of language ability. Daniel Dennett and Terrence W. Deacon regard the BE or Baldwinian evolution as a key concept of language evolution; however, their scenarios are different. According to Dennett, the BE is essential to explain the genetic acquisition of a complex trait such as the innate ability for language acquisition, which is impossible
to acquire by evolution alone, because it is of value only when it is completed (by the help of learning) (Chapter 4). Hinton and Nowlan's experimental result [6] is a typical case of such a scenario. On the other hand, Deacon regards Baldwinian evolution as a kind of evolution based on cultural niche constructions in a broad sense (Chapter 5). He points out that the use of symbolic communication results in the construction of a new cultural niche that brings about the evolution of other traits, which support the learning process of the language rather than the acquisition of innate predispositions for certain grammatical constructions. Thus, learning becomes more and more important, which results in a further construction of a cultural niche through the adaptive evolution of language. The evolutionary significance of niche construction and its relationship with the BE are discussed by Godfrey-Smith, Dennett, and Deacon in Chapter 6.

The next four chapters discuss the significance of the BE in developmental biology. Celia L. Moore and Susan Oyama point out that the old dichotomy of innate and acquired traits is inappropriate, because these are connected to each other by the developmental process in nature. Moore emphasizes the existence of nonobvious experience throughout behavioral development, such as maternal effects on rat pups, and argues that the heredity of traits should be considered as the first developmental stage of an organism (Chapter 7). Oyama also points out that adaptation should be identified by asking whether, and how, the interactions of organisms with their surroundings increase the probability of recurrence of similar interactional patterns in successive generations of offspring (Chapter 9). Brian K. Hall points out that many regard the BE and genetic assimilation as synonymous, although these two processes are not the same: The former requires mutations for the learned trait to become the innate one, but the latter does not (Chapter 8). This is because Waddington focused on the expression of hidden genetic variability, which is supposed to be previously buffered through canalization, in response to selection following an environmental stimulus. Paul E. Griffiths states that the term “social heredity,” which was also defined by Baldwin [2, 3], corresponds to epigenetic inheritance and niche construction in modern terms (Chapter 10). In addition, he points out that the BE is not necessary for these mechanisms to play a significant role in evolution.

In Chapter 11, Ruben R. Puentedura argues that the BE is observed in several extended versions of Hinton and Nowlan's model [6]. He also introduced the result of Ackley and Littman's experiment—another well-known computational experiment on the interactions between evolution and learning [1]—as a case in which there is a gap between the genetic and learning exploration processes. However, he points out that their results are not a case of the BE, in that the learned behavior was not genetically assimilated into the innate behavior, because the plastic and fixed tasks are not correlated.

The final four chapters discuss the evolution of mind or consciousness as an ultimately plastic trait. Scott F. Gilbert discusses the possibility that cognition and mind originated in the context of predator-induced polyphenism, which is the ability of the organism to alter development in a manner that would increase its fitness (Chapter 12). Jesper Hoffmeyer and Kalevi Kull also discuss the significance of Baldwinian thinking in view of phenotypic plasticity for semiotic competence, which can lead to the emergence of consciousness (Chapter 13). Deacon classifies what we call emergent phenomena into three levels and points out that genetic and cultural evolution correspond to third-order emergence, which arises from the hierarchical structure of second-order (self-organizing) and first-order (supervenient) emergence (Chapter 14). Bruce H. Weber, the other editor of this book, sums up all the discussions and concludes that the mechanisms explored in this book should be considered seriously if it is believed that human agency and action played a role in evolutionary emergence of the human mind (Chapter 15).

As summarized above, in this book there are many valuable discussions on the BE from a variety of viewpoints. However, several points should be added with regard to recent interest and progress in so-called evo-devo and eco-devo. The BE and related concepts have caught the attention of evolutionary developmental biologists for a decade; however, they are still seen as controversial issues [4, 13, 20]. For example, as discussed in several chapters, the distinction between the BE and genetic assimilation is confusing. While Hall emphasizes the necessity of mutations for the occurrence of the BE (Chapter 8),
West-Eberhard holds a different view [20]. In addition, she proposes a general scenario of adaptive evolution through phenotypic and genetic accommodation, which takes the two-step nature of evolutionary change and the developmental plasticity of organisms into consideration [20]. Her claim is that genetic accommodation (i.e., gene-frequency change due to selection on variation in the regulation, form, or side effects of the novel trait) includes both the BE and genetic assimilation.

At the same time, various empirical evidence on the BE has recently been reported. For example, Crispo has summarized the various experimental results corresponding to the concepts mentioned above, and discussed the differences between them [4]. In particular, the growing field of insect learning has revealed that learning is a universal property of insects, which rely on it for all major life functions [5]. Mery et al. have observed interesting phenomena that are supposed to be the results of the BE in evolutionary experiments of the learning behavior of oviposition substrate choice in *Drosophila melanogaster* [10], which have shown both guiding and hiding effects of learning [7].

Theoretical and computational approaches to the BE or phenotypic plasticity should be paid more attention. The role of phenotypic plasticity in evolution has been considered theoretically [13]. ALife and other computational approaches have also contributed to the understanding of the BE since the study by Hinton and Nowlan [6], and a special issue on the BE in evolutionary computation has been published [17]. As Puentedura briefly mentions in Chapter 11, an important finding of these studies is that the balances between the benefit and cost of learning are essential for the occurrence of complex evolutionary scenarios through the BE [7, 12, 15]. Suzuki and Arita recently showed that the BE can occur repeatedly on dynamically changing fitness landscapes that arise from communicative interactions among individuals, and facilitate genetic evolution as a whole [16].

Moreover, ALife approaches can contribute to the several specific topics in this book. Artificial embryogeny or development is one of the recent topics in the ALife field [9], and how the developmental process mutually connects innate and acquired traits can be discussed in this context. Nevertheless, there are still few studies on the BE in this context. Further, the role of learning in language evolution has been discussed in various studies [11, 16, 21]. Watanabe et al. recently investigated the interaction between evolution and learning of language by using a computational model into which both cultural learning of language and genetic evolution of language ability are incorporated [19]. They pointed out that the factors specific to language evolution (such as adaptive shift in language, or overlearning of language from a variety of parents) are important for the occurrence of the second step in the BE. It will be interesting to further clarify whether Dennett’s or Deacon’s scenario appears in various conditions of ALife models of language evolution. Also, learning and niche construction are basically different processes in that the former is a change in the trait of the learning individual itself and the latter is a change in the surrounding environment of the niche-constructing individual. But both effects on evolution can be interpreted as changes in the shape of fitness landscapes. The ALife models into which both processes are incorporated (such as [22]) will clarify how the interactions between them bring about more complex dynamics of evolution.

In conclusion, although there are several points that need to be added, this book will be a valuable guide for ALife researchers who are interested in a deeper understanding of the interactions between evolution and learning, and related concepts or phenomena.

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