



Eva Jablonka and Marion Lamb (2005)
Evolution in Four Dimensions - Genetic, Epigenetic, Behavioral, and Symbolic Variation in the History of Life
MIT Press, hardback 462 pages.

review by Gert Korthof. 24 Apr 2005

Jablonka and Lamb claim that there are four inheritance systems: genetic, epigenetic, behavioral and symbolic inheritance in evolution. Consequently, not all evolutionary adaptations can be attributed to the selection of blind genetic mutations in DNA. Induced and acquired changes play also a role in evolution.

The **first** dimension is the DNA based genetic system. The authors present good examples of non-random semidirected mutations. The neo-Darwinian dogma that all mutations are random must be refined. There are degrees of randomness. Some mutations occur at higher probabilities at specific locations in DNA. Furthermore, they are inducible by the environment and they have a higher probability of being adaptive. It is an open question how wide-spread these mechanisms are in evolution.

Epigenetic inheritance is the **second** dimension in evolution. The authors present two convincing examples of non-genetic heritable variation (epigenetic) that is transmitted to the next generation. Evidence showing that this type of non-genetic inheritance is important in evolution is still lacking (1). However, it cannot be excluded that it has a role in evolution. So, new ways of thinking about the neo-Darwinian dogmas and Lamarckism are required.

Behaviour is the **third** dimension in evolution. Examples of animal behaviour that is transmitted to the next generation without DNA being involved are: food preferences of adult rabbits after exposure to juniper berries during pregnancy; mother imprinting of ducklings; Israeli black rats learning to strip pine cones, British tits learning how to get cream out of milk bottles; bird song imprinting, cultural traditions in African chimpanzees and Japanese macaques.

Culture and especially human language (symbols) is the **fourth** dimension in evolution. Cultural evolution has properties similar to biological evolution: cultural innovation (similar to genetic variation), cultural transmission (similar to heredity) and differential multiplication and survival of culture (similar to natural selection). Interesting examples of the interaction of genes and epigenetic systems are given. Some chromosomal regions are more sensitive to mutations than others due to epigenetic marks on DNA (methylation marks). Not only the rate and the location, but also the timing of mutations can be non-random. The authors point out that epigenetic inheritance is a precondition for the evolution of multicellular life. An organisms ability to produce different cell types is based on cell memories and these are based on epigenetic inheritance. Genomic imprinting is an intriguing example of epigenetic inheritance.

The book is accessible, thoughtfully composed, most of the time a pleasure to read, but some parts require more effort, nicely illustrated and educational. There are no exaggerated claims. Evidence and arguments are presented in balanced way. Self-critical dialogues at the end of each chapter. Unquestionably a valuable contribution to the 'Third Evolutionary Synthesis'.

Postscript

May 2014 a new revised edition has been published with a substantial new chapter. See publisher [info](#). From the new Preface: "... our view that the old, gene-based, Modern Synthesis version of evolutionary theory is inadequate for the twenty-first century."

Notes

1. "The classical model postulates that at fertilization, a targeted, although widespread, catalytic process actively removes DNA methylation contributed by the paternal gamete. ... After fertilization, there appears to be a passive loss of global DNA methylation levels." *Nature* 19 Apr 2012.

Reviews

- Massimo Pigliucci (2005) wrote an approving review "Expanding evolution. A broader view of inheritance puts pressure on the neo-darwinian synthesis.", *Nature*, 435, 565. 2 Jun 2005
- Oren Harman (2006) 'The Evolution of Evolution' a review of 'Evolution in Four Dimensions: Genetic, Epigenetic, Behavioral, and Symbolic Variation in the History of Life' by Eva Jablonka and Marion J. Lamb. Post date 08.30.06 Issue date 09.04.06 (subscription required).
- Mary Jane West-Eberhard, 'Dancing with DNA and flirting with the ghost of Lamarck', a review of: 'Evolution in Four Dimensions', *Biology and Philosophy* Volume 22, Number 3, June, 2007.

"In sum, *Evolution in Four Dimensions* describes modern findings and fascinating examples showing that long-held beliefs about inheritance deserve reconsideration. In that respect, the book merits attention by all biologists. With its agreeable style it will painlessly raise their level of sophistication regarding different modes of inheritance, and the potential importance of non-genetic inheritance for evolution and during the history of life. In this book, the reader has the impression of being in the company of an amiable pair of rebels who rightfully stir up a complacent public. They cajole and educate us into being more broad-minded about the basic tenets of heredity and evolution. But the revolution in evolutionary biology, if it is to occur, will concern not so much the mechanisms of heredity - in fact, one of the strongest points of the earlier Synthesis - but the environmental causes of developmental variation of all sorts, not just inherited variation; and it will focus on the relation of that variation to modern genetics, as research on gene expression and associated genomic processes (like methylation, chromosomal condensation, alternative splicing and environmentally modulated mutation rates) converges with research on development and the phenotype, including the behavioral phenotype. Jablonka and Lamb have written an erudite and engaging book that will appeal to anyone who enjoys informed criticism, and who is interested in forward-looking ideas about heredity, development, and evolution."

- Gerdien de Jong (2007) [Much Ado...](#) *Ethology* 113 (2007) 730–732 is a critical review of *Evolution in Four Dimensions*:

"The authors argue that the genetic system is only one of four inheritance systems – epigenetic, behavioural and symbolic inheritance – into account, it is possible 'to construct a far richer and more sophisticated theory of evolution, where the gene is not the sole focus of natural selection'. In doing so, they want to argue four points: (i) that there is more to heredity than genes; (ii) that some hereditary variation is non-random in origin; (iii) that some acquired information is inherited; and (iv) that evolutionary change can result from instruction as well as selection. ... Jablonka and Lamb possess no evidence for a directed adaptive mutational response to change."

Conclusion: epigenetics is Much Ado About Nothing!

Further Reading

- Eric J. Richards (2006) Inherited epigenetic variation - revisiting soft inheritance". [Nature Review Genetics](#) p395 | 10.1038/nrg1834. Summary: A growing body of evidence indicates that epigenetic states can be influenced by the environment. Considering that erasure of epigenetic marks between generations is not universal among multicellular organisms, what are the potential implications of inherited epigenetic variation for current theories of inheritance and evolutionary change?
- Nature Insight: Epigenetics. 24 May 2007. Vol. 447, No. 7143 pp 396-440. Several Free Access articles: [Perceptions of epigenetics](#). "In this article, I give examples of how epigenetic phenomena are studied and interpreted, and I propose a revised definition that embodies contemporary usage of the word."
- C. David Allis, Thomas Jenuwein, Danny Reinberg, Eds. (2007) *Epigenetics*, Cold Spring Harbor Laboratory Press, 2007. 512 pp. Review: *Science*. "An epigenetic phenomenon is a change in phenotype that is heritable but does not involve DNA mutation."
- Eva Jablonka and Marion J. Lamb (2007) 'The expanded evolutionary synthesis -a response to Godfrey-Smith, Haig, and West-Eberhard', *Biology and Philosophy*, Volume 22, Number 3 / June, 2007
Abstract: "In responding to three reviews of *Evolution in Four Dimensions* (Jablonka and Lamb, 2005, MIT Press), we briefly consider the historical background to the present genecentred view of evolution, especially the way in which Weismann's theories have influenced it, and discuss the origins of the notion of epigenetic inheritance. We reaffirm our belief that all types of hereditary information -genetic, epigenetic, behavioural and cultural- have contributed to evolutionary change, and outline recent evidence, mainly from epigenetic studies, that suggests that non-DNA heritable variations are not rare and can be quite stable. We describe ways in which such variations may have influenced evolution. The approach we take leads to broader definitions of terms such as "units of heredity", "units of evolution", and "units of selection", and we maintain that "information" can be a useful concept if it is defined in terms of its effects on the receiver. Although we agree that evolutionary theory is not undergoing a Kuhnian revolution, the incorporation of new data and ideas about hereditary variation, and about the role of development in generating it, is leading to a version of Darwinism that is very different from the gene-centred one that dominated evolutionary thinking in the second half of the twentieth century."
- Peter Godfrey-Smith (2007) '[Is it a revolution?](#)', *Biology & Philosophy*, Volume 22, Number 3 / June, 2007.
Abstract: "Jablonka and Lamb's claim that evolutionary biology is undergoing a 'revolution' is queried. But the very concept of revolutionary change [Thomas Kuhn] has uncertain application to a field organized in the manner of contemporary biology. The explanatory primacy of sequence properties is also discussed."
Introduction: "On the first page of *Evolution in Four Dimensions*, Jablonka and Lamb (J&L) claim that "biological thinking about heredity and evolution is undergoing a revolutionary change" (p. 1). The views that are allegedly being replaced include the orthodox gene-centered approach to cell biology, and a related set of strictly Darwinian ideas in evolutionary theory. These views are linked by the concept of inheritance, which is the main focus of J&L's book. Whereas mainstream biology has organized itself around the view that biological inheritance always (or almost always) involves the transmission of genes across generations, J&L recognize four 'dimensions' of heredity, the genetic, epigenetic, behavioral, and symbolic. All four figure in evolutionary processes, sometimes alone and sometimes in complex interaction. The result, for J&L, is not just a richer and more complicated picture, but one with qualitative differences from mainstream views. In particular, J&L insist on describing the upshot of various new findings as a partial vindication of 'Lamarckian' ideas". (interesting! Central Dogma, information, Kuhnian revolution).
- David Haig (2007) 'Weismann Rules! OK? Epigenetics and the Lamarckian temptation', *Biology and Philosophy*, Volume 22, Number 3 / June, 2007.
- Massimo Pigliucci weblog April 01, 2009 [Epigenetic what?](#)
- Richard C. Francis (2011) *Epigenetics: The Ultimate Mystery of Inheritance*, W. W. Norton: 2011. "Francis's thoughtful and succinct book focuses on the narrative and the excitement of discovery" (from *Nature* review 29 sep 2011)
- Nessa Carey (2011) *The Epigenetics Revolution: How Modern Biology is Rewriting Our Understanding of Genetics, Disease and Inheritance*, Icon Books. "Carey's book is more DNA-centric, focusing on epigenetic mechanisms and the chemistry of chromatin, which defines how DNA is packaged around proteins in the nucleus. Her book combines an easy style with a textbook's thoroughness." ... "Carey's lively vision of how DNA works resembles a film script, with "plenty of room for interpretation and retakes", noted reviewer Jonathan Weitzman from *Nature* review 29 sep 2011.
- *Transformations of Lamarckism: From Subtle Fluids to Molecular Biology* (Vienna Series in Theoretical Biology) Eva Jablonka (Editor), Snaib B. Gissis (Editor), Anna Zeligowski (Illustrator) (2011) [The MIT Press](#), 480 pages. Sample chapters available.
- Information on [Epigenetics](#)
- Elizabeth Pennisi (2013) Evolution Heresy? Epigenetics Underlies Heritable Plant Traits, *Science* 6 Sep 2013 [new evidence for heritable epigenetic controlled phenotypic variation in plants (*Arabidopsis*)]
- "We are coming to understand that social learning is not restricted to large-brained animals but is instead widely distributed—it is present, for example, in crickets—and that it is a powerful participant in evolutionary processes (Jablonka, Lamb (2005) *Evolution in Four Dimensions*)". *Science* 15 nov 2013.
- Jocelyn Kaiser (2014) [The Epigenetics Heretic](#), *Science*, 24 January 2014: Vol. 343 no. 6169 pp. 361–363. Michael Skinner's claim that chemicals can cause changes to gene expression that persist across multiple generations of animals has stirred excitement—and outrage.
- [A conference on hype in science](#), April 25, 2014. See section about epigenetics!
- Eva Jablonka, Marion J. Lamb (2020) *Inheritance Systems and the Extended Evolutionary Synthesis*, Cambridge University Press (June 4, 2020) paperback 96 pages.

