Computational Cognitive Epigenetics[1]

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(Commentary on Eva Jablonka and Marion Lamb: *Evolution in Four Dimensions: Genetic, Epigenetic, Behavioral, and Symbolic Variation in the History of Life*, MIT Press, 2005
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Abstract:

Jablonka & Lamb (J&L) refer only implicitly to aspects of cognitive competence that preceded both evolution of human language and language learning in children. These aspects are important for evolution and development but need to be understood using the design-stance, which the book adopts only for molecular and genetic processes, not for behavioural and symbolic processes. Design-based analyses reveal more routes from genome to behaviour than J&L seem to have considered. This both points to gaps in our understanding of evolution and epigenetic processes and may lead to possible ways of filling the gaps.

Jablonka & Lamb's (J&L's) book exposes many tangled connections between genome, behaviour, and environment, but it skims over gaps in our knowledge about the information-processing capabilities underlying observed behaviours – ignoring important mechanisms with epigenetic features. Much is said about the physical and chemical mechanisms involved in development, but behavioural competences are described mostly from the outside. Explaining the internal information processing requires the design stance (Dennett 1978).

External behaviours of many animals indicate that they have mechanisms concerned with internal symbolic competences, required for perceiving or acting in structured situations, including planning, predicting, identifying information gaps to be filled, formulating goals, executing plans, learning generalisations, and creatively combining different competences. We need to explain what these competences are, what mechanisms make them possible, how they develop in individuals, and how they evolved. Such competences (in humans and other animals) seem to presuppose something like internal symbolic languages with very specific properties.

When the variety of structurally different combinations of situations and goals rules out preconfigured responses, animals need the ability to represent and make inferences about existing and future configurations and changes; for example, configurations of a partially constructed nest made of interlocking twigs and the affordances (Gibson 1979) for inserting the next twig. This requires internal formalisms for representing structures and possible processes and for constructing, comparing, and planning, including selecting actions from branching collections of possible future sequences. Later, the animal has to produce the actions under the control of the representation. So action sequences linked to complex internal symbolic structures occurred before external linguistic behaviour evolved.

Animal behaviours demonstrating such competences include tool-related behaviours (Kacelnik et al. 2006) and the remarkable symbolic competences of the grey parrot Alex

1 In Behavioral & Brain Sciences Journal, Vol 30 No 4.2007. Commentary on Jablonka and Lamb, 2005

(Pepperberg 2004).

Our epigenetic hypothesis about how information-processing develops under the influence of the environment avoids two extreme theories; first, that all animal competences are somehow encoded separately in the genome, possibly in a large collection of innate modules, and second, that a small collection of general learning mechanisms (e.g., reinforcement learning) is genetically determined and that everything else is a result of applying those general learning processes.

Our "middle way" also synthesises two apparently opposed views expressed by Karmiloff-Smith (1994, p. 693), "Decades of developmental research were wasted, in my view, because the focus was entirely on lowering the age at which children could perform a task successfully, without concern for how they processed the information," and Neisser (1976, p. 8), "we may have been lavishing too much effort on hypothetical models of the mind and not enough on analysing the environment that the mind has been shaped to meet."

What an individual can learn often changes dramatically during its life, indicating a cascaded development of competences partly under the influence of the environment, including competences to acquire new competences (metacompetences), some of which are themselves the result of interaction of earlier metacompetences with the environment. We summarise this relationship in Figure 1, showing multiple routes from the genome to behaviours of various sorts, with competences at different levels of abstraction and different sorts of specificity developed in different ways at different stages. This implies that learning in some parts of the brain is delayed until others have acquired a layer of competences to build on. So if prefrontal lobes are associated with processes further to the right of the diagram, occurring only after many cycles of simpler development, we would expect prefrontal lobes to develop after low-level visual and motor control mechanisms. Evidence consistent with this conjecture has recently been reported in human infants by Gilmore et al. (2007).

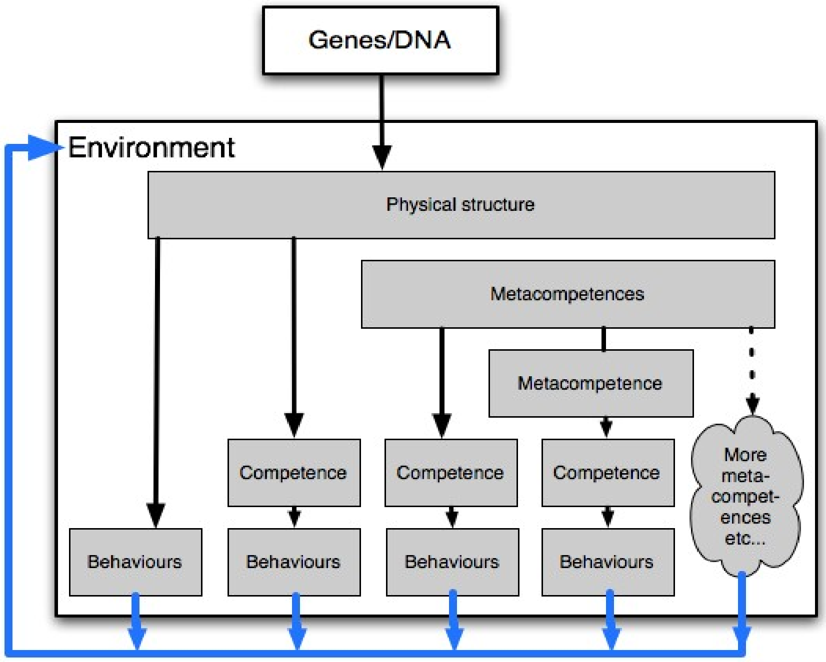

Figure 1 (Based on Chappell & Sloman, 2007). The environment (including the body and new brain states) can affect all the processes. There are multiple routes from genome to behaviours, some of which are used only after others have produced new competences and metacompetences.

J&L discuss the evolution of language and, like many others (e.g., Arbib 2005), focus mainly on external language used for communication. This assumes that first there were simple forms of language (e.g., gestures and sounds), and complex forms evolved later.

In contrast, we suggest that language first evolved for "internal" use. Because some people restrict the label "language" to symbol systems used for external communication, we use the term *g-language* (generalised language) to refer to a wider class that includes internal languages. A g-language allows rich structural variability of various kinds as well as (context sensitive) compositional semantics for dealing with novel configurations of objects or processes.

Most people assume that language started simple and external and then grew more complex externally before being internalised. We, like Bridgeman (2005), suggest that complex g-languages evolved in many non-human species, and also develop in young children, who cannot yet talk. Internal g-languages are needed to provide forms of representation of current and possible future situations and processes that allow wide structural variation in what is represented, with compositional semantics to cope with novelty (Sloman 1979). So, rich internal g-languages are precursors to external human languages both in evolution and in child development. After g-languages had evolved for other purposes, including constructing plans that were used to control behaviour, some animals may have started mapping their internal structures onto external behaviours for communication purposes.

Insofar as animals and children can look at different parts of a scene and combine information from most recent saccades with information about parts of the scene that are no longer in view, for example, when planning what to do, they must use representations of spatial organisation of information as well as temporal organisation. In some ways, this requires more complex forms of representation than human spoken languages, combining aspects of verbal language and pictorial languages (analogous to maps, diagrams, and drawings; see also Trehub 1991).

G-languages probably evolved for internal information processing and control of behaviour (through the generation of goals, plans, or instructions), along with generation of questions to specify missing information, and perhaps to formulate hypotheses, explanations, and suppositions. External human language (spoken and gestural) and other symbolically based aspects of human culture (e.g., music, mathematics, and so on) also might have built on these preexisting internal symbolic foundations.

Eventually, instead of a specific g-language, evolution produced competences to acquire a variety of g-languages expressing different kinds of information. This implies that some nonhuman animals' behaviour will be directed and shaped by their internal g-languages, which in turn are shaped by the structure of the external environment, directing evolution down particular paths, and perhaps causing "convergent" evolution of closely related cognitive abilities in birds and mammals with overlapping perceptual and manipulative competences.

If abstract and complex g-language constructs have to be learnt at a late stage of development, but are particularly useful to a species, then some of them could become genetically assimilated or accommodated, in which case they will themselves become heritable and can direct development in particular ways. Environmental cues encountered by these animals will be filtered through their cognitive architecture, thus tightening the knots between the genome, the behaviour, and the environment. Chappell and Sloman (2007) suggest that this employed a separation between the parts of the mechanism producing a general class of behaviours and the parts that provide parameters that select from that class. The generic competence and the particular parameters might undergo separate trajectories in evolution and development.

If J&L's "assimilate-stretch" principle were extended to cope with the evolution and development of internal g-languages and associated mechanisms, this might be a significant, previously unnoticed, factor in the evolution of cognition. Their examples, however, suggest that assimilate-stretch extends behaviour additively. But qualitatively new capabilities might emerge. For example, if a learned capability becomes genetically assimilated or accommodated, it could form a building block for qualitatively diverse competences. Information that some objects can be deformed by manipulation, can be broken into smaller pieces, can be inserted into spaces, and can, if appropriately assembled, produce fairly rigid structures, might form fundamental parts of a very complex collection of learnable competences, including constructing nests, making or using tools, or extracting objects from containers.

The ideas in this book may turn out to have far-reaching significance for many disciplines. We have tried to show, briefly, how some of that could affect studies of cognition, and internal g-languages, with implications for the evolution of language and many forms of learning. As our cited paper indicates, these forms of development may be required also for intelligent robots that are learning to cope in a wide variety of environments.[2]

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Track 56: Epigenetics. Track 57: Evolutionary Psychiatry. Track 58: Exercise and Sports Psychiatry.Â Previously Published Papers on "Computational Modeling in Cognitive Science Conference". Attribute Analysis of Quick Response Code Payment Users Using Discriminant Non-negative Matrix Factorization. Authors: Hironori Karachi, Haruka Yamashita, Keywords: Data science, non-negative matrix factorization, missing data, quality of services. Computational epigenetics uses statistical methods and mathematical modelling in epigenetic research. Due to the recent explosion of epigenome datasets, computational methods play an increasing role in all areas of epigenetic research. Research in computational epigenetics comprises the development and application of bioinformatics methods for solving epigenetic questions, as well as computational data analysis and theoretical modeling in the context of epigenetics. This includes modelling of the The Computational Epigenetics Group pursues three goals: To foster our understanding of epigenetics and disease by computational means, and to work toward optimized therapies. To develop advanced bioinformatic methods for the analysis and interpretation of large epigenome datasets. To establish â€˜computational epigeneticsâ€™ as a relevant and exciting field at the intersection of epigenetic and bioinformatic research.