**EMBO reports article for Science & Society**

**The Biosocial Genome?**

**Interdisciplinary Perspectives on Environmental Epigenetics, Health and Society**

**Introduction**

In recent years, research on how the human environment and the ways we live influence gene expression has generated considerable scientific and public interest. Articles in prominent international newspapers with headlines such as “Why your DNA isn’t your destiny” (Time Magazine in 2010) or “Poverty leaves traces in children’s genome” (Die Süddeutsche Zeitung in 2016) have introduced the public to the emerging field of environmental epigenetics. This is a sub-division of the much more heterogeneous research field of epigenetics, which we regard here as research concerning how interactions between the environment and the genome can lead to epigenetic modifications that affect gene expression. Environmental epigenetics is often heralded as providing a revolutionary perspective on disease etiology, particularly with regard to so-called “life style diseases” such as cardiovascular disease or diabetes. It is also often presented as an important new framework for understanding varied susceptibility and resilience in relation to mental illness and the long-term effects of environmental agents such as toxins.

Through its emphasis on the environment, environmental epigenetics often engages with the social context of individuals and populations. Studies investigate, for example, how socio-economic status, exercise habits, diet or experiences of trauma might influence biological processes at the molecular level. This makes environmental epigenetics a field of great interest for social scientists and humanities scholars. It also raises a number of questions that might be situated at the intersection of these disciplines; for example, around how to conceptualize the social environment in a laboratory context. For this reason, a group of international scholars from the life sciences, social sciences and humanities came together in Munich in January 2017 to discuss the novel perspectives on the entanglement of social experiences and biological processes that environmental epigenetics raises and assess its potential social and poltical implications. Here we present some of the main findings that emerged from this interdisciplinary workshop. While we stress the potential of the field for elucidating how human society affects human biology, we also caution against over-simplified translations from social structures to biological processes and *vice versa*.

**Genes and Their Environments**

Although traditionally epigenetic research has been mostly concerned with understanding the basic mechanisms of cell differentiation and cell identity, in the public sphere examples of research in environmental epigenetics have often come to stand for epigenetics research as such. This has been due to a number of controversial, propositions that environmental epigenetics raises which have caught the attention of the wider public as well as scientists. Environmental epigenetics proposes that the environment might play a bigger role in gene regulation and expression under a wider range of circumstances than was previously assumed, taking in both material and psychosocial factors (Skinner, 2011).

Studies in environmental epigenetics have explored, for example, the effects of air pollution, pesticide exposure, physical exercise and emotional stress on the epigenome of the human body. While some studies emphasize the potentially pathological effects of such exposures on adult health, others focus on the impact on the developing body during prenatal and early postnatal life. The latter have been particularly prominent in the public domain as they concern for example how maternal nutrition or early life stress affects the epigenome of the offspring to produce later detrimental effects on behavior or risk of chronic disease. Here, environmental epigenetics is in close conversation with research on the Developmental Origins of Health and Disease (DOHaD), which explores how events during early life development can shape later life chances of health and illness (Gluckman & Hanson, 2008). further and often controversial line of research concerns how environmental effects could be passed across generations via epigenetic modifications, in a manner reminiscent of Lamarckism.

While studies in environmental epigenetics might help us to account for the impact on health of environmental exposures and experiences, there are certain limitations to current research. On the one hand, many of the fundamental studies in environmental epigenetics have been conducted in rodents, raising questions about the validity of extrapolating from animals to humans. Studies in human cohorts and patient groups, on the other hand, are often limited by the availability of appropriate samples, as epigenetic processes are likely to be tissue-specific, so samples from peripheral blood may not reflect epigenetic changes in, for example, the brain or the liver. Further, the costs of performing epigenetic measurements are high, and there is seldom adequate replication of findings across human cohorts or patient groups. Demonstration in the lab of the functional validity of any epigenetic effects found in human tissues is often not undertaken. Finally, the range of possible epigenetic changes is extensive, involving DNA methylation, modifications to histone proteins and a wide range of non-coding RNAs. Even DNA methylation, the most studied epigenetic modification, can occur in several ways and at multiple sites in the genome, with the pattern being important in the resulting effects on gene expression. There is increasing evidence too for the importance of interactions between epigenetic effects and genetic changes. In view of these complexities, the study of epigenetics poses considerable challenges in bioinformatics, to a much greater extent than studies of genetic variations alone.

Despite these limitations and the significant controversies around certain claims (such as for transgenerational inheritance), there are several reasons why a more detailed consideration of the premises and social and political dimensions of environmental epigenetics is now timely. First, its findings currently circulate widely not only in biological research, but also in the media, where it is invoked in relation to numerous social phenomena such as the so-called obesity epidemic or politically more contentious issues such as the mental health status of refugees and the possible inherited effects of trauma. Secondly, as evidence from environmental epigenetics moves through science and society, research findings have the potential to affect policy in areas such as public health and environmental and social policy: some argue that this is already apparent in recent UK policy documents on the effects of poverty on childhood development (Edwards, Gillies et al., 2015). As epigenetics research might begin to inform policy, it is important to explore and discuss the explicit and implicit assumptions about the relationship between biological and social factors which underlie the findings. Thirdly, environmental epigenetics can been seen as an instance of a wider shift in the molecular life sciences towards what has been described as a “postgenomic” perspective, which considers biology as plastic and open to environmental processes as opposed to being determined by inherited fixed genetic influences (Meloni, 2014). This opens up novel opportunities for collaboration between researchers in biology, the social sciences and the humanities.

**Biology and Society**

Researchers from the social sciences and humanities have been engaging with environmental epigenetics for a while. For many in these fields, research perspectives that included a stronger focus on the role of the environment in health and disease constituted a welcome move away from an emphasis on the role of genes in isolation from environments within and beyond the body. This shift resonated with findings from the social sciences that emphasize that bodies are embedded in their environments and that social contexts shape patterns of health and disease. From a social science and humanities perspective, two features of environmental epigenetics stand out as particularly powerful for providing insights into the relationship between social experiences and biological processes: first, environmental epigenetics research is predicated on the concept of the body as open to environmental pressures. Many features of the environment in which humans develop and live are the result of human activity, such as the quality of food or the built environment. In this sense, environmental epigenetics can be said to open up social and political questions from the outset. Highlighting the fact that the development of health and disease is often mediated by social factors, it points to the need for new ways of conceptualizing the extrinsic factors associated with health inequalities in fields such as toxicology, or mental health research.

Secondly, environmental epigenetics proposes new ways of thinking about the temporal dynamics of health and disease, across the life course of an individual and also across generations. In particular, it has been argued that there are so-called ‘critical windows’ of development in prenatal and early postnatal life in which environmenal influences such as nutrition, toxins or trauma can affect later life health outcome. This raises questions for public health in terms of how to address the potential long-term effects of unequal living conditions that might limit an individual’s range of action in terms of maintaining and improving their own health and that of their children.

It is important to note that this emphasis on the influence of the environment on phenotype formation is not a new proposition. Although sometimes heralded as a radical new perspective in biology, environmental epigenetics is part of a long history of considering and negotiating the relationship between the environment and the body. The notion of human biology being malleable to environmental factors was present in Aristotle’s theory of embryonic epigenesis. The idea that environmental influences could ‘damage’ biology was also central to the emergence of progressive public hygiene and social medicine movements in the 19th century. Conversely, it played a key role in late 19th century concerns about ‘degeneration’ which focused on how the living conditions of industrial societies might affect the hereditary material of nations and so-called ‘races’; such concerns fed into the eugenic movements of the early twentieth century which sought to limit the reproduction of those deemed biologically inferior (Bashford and Levine, 2010). From an historical point of view, the later twentieth century focus on the gene as a primary determinant of bodily development and the associated separation of the biological from the social, is the exception rather than the rule. In considering the potential and the challenges of environmental epigenetics, it is important to keep in mind the longer history of ideas about the relationship between biology and the environment, and their complex sociopolitical implications.

**Challenges of Biosocial Science**

Thinking about the social and the biological as strongly connected opens up numerous opportunities, but also challenges, for contemporary science and society. In our workshop we identified particularly three challenges that merit closer attention across disciplines.

***Experimental Reductionism and the Exclusion of Social Complexity***

Environmental epigenetics tends to locate the development of health and disease primarily at the level of individual bodies and behaviors, at the expense of more structural views that encompass the social, political, and economic determinants of health. This may appear paradoxical as, after all, environmental epigenetics concerns how *environmental* factors affect gene expression. However, much depends on exactly how the environment is conceptualized within research – and there are factors that might lead to a narrow understanding of the environment in epigenetic research.

Experimental studies on the epigenetic effects of ‘maternal care’ offer an illustrative example for such restriction of the experimental environment. In this field, the work of Moshe Szyf, Michael Meaney and colleagues (Weaver, Cervoni et al., 2004) has become iconic. In a series of experiments, they set out to investigate the *programming* effects of maternal behavior on offspring in rodents, showing that the degree to which dams lick and groom their pups – what the researchers called ‘maternal care’ – changes the epigenetic profile in the hippocampus of their pups. The offspring that had been licked and groomed less showed reduced expression of the glucocorticoid receptor gene, while frequent licking and grooming had the opposite effect. The researchers argue that the licking and grooming behavior of the dam altered stress responses in her pups, in particular to more anxious behavior in those pups which received less ‘maternal care’. While some researchers have questioned the validity of these results and of their interpretation, today these experiments are foundational to a strand of research that explores the epigenetics effects of early life stress, deprivation and trauma in rodent model organisms.

In media presentations and in the peer-reviewed literature alike, these experiments are frequently linked to the influence of the behavior of human mothers on the psycho-physical development of their children. Two aspects are particularly striking about this translation. The first is how seamlessly findings in the rat are tranposed into human contexts. This has been achieved by comparing epigenetic studies in rats to selected psychological studies in humans without adaquate discussion of species-typical behaviours, developmental differences, or any reference to controversies about the interpretation of the studies within their own fields (Kenney & Müller, 2017). Second, it is remarkable how isolated the figure of the mother appears in discussions that bring together rats and humans. Basic science research requires control of the experimental conditions to permit verifiable interpretation. But this can be problematic if it leads to the exclusion of important factors as potentially confounding or contributing variables. For example, in exploring the hypothesis that maternal behavior shapes the epigenetic profiles of rat pups, factors such as peer relations, or the role of fathers – important in humans but not rats – are not considered. As a result, when these experimental findings are transposed to humans, the importance of optimizing maternal behavior comes to be discussed in isolation both from other factors that shape child development and from factors that shape the lives of mothers but which may be beyond their control.

This tendency to narrowly generalize from the experimentally-controlled conditions of animal model research to more complex human contexts is also illustrated by research on the intergenerational aspects of childhood obesity, a condition that has become a major public health concern. Most research in this area focuses on how maternal body weight, nutrition before and during pregnancy, and the food a mother feeds her child during their early years might induce a propensity for childhood obesity via epigenetic mechanisms. Many of these studies use socio-economic status (SES) as a variable in their study design, finding associations between higher body weight and poor nutrition in low SES mothers, both of which have been labeled as risk factors for childhood obesity. Given this focus, discussions of possible interventions often focus on educating mothers about how to eat better and lose weight before pregnancy. At the same time, we know that the risk of obesity and malnutrition is distributed unequally across society, with low income individuals being particularly affected due to reduced access to healthy foods (so-called ‘food deserts’) or physical exercise facilities. Similarly, the ability to breast feed can depend on SES and the possibility of flexible working arragements or extended maternity leave. The point is that if we hope to translate the findings of epigenetic research on the developmental mechanisms linking nutrition with disease risk into effective health policy, it is imperative that we view nutrition not as a simple exposure in isolation, or a function of individual choice, but as a resource that is constrained in complex ways by social institutions and structural assymetries that distribute resources, and chances to health, unevenly across society.

***A Focus on Durability and the Question of Reversibility***

Much research in environmental epigenetics concerns its role in the phenotypic changes occurring during development, or those operating in the early stages of disease. Even though these are circumstances when substantial phenotypic effects occur, there is a tendency in life sciences research towards a narrow focus on the durable positive or, more often, negative epigenetic effects of environmental factors. This is evidenced by the widespread use of the metaphor of ‘programming’ (Stelmach & Nerlich, 2015), which is misleading in that it implies that the phenotypic outcome is certain from the first inception of a programme - rather than being affected by a range of environmental factors over a sustained period. The related concepts of ‘critical or sensitive’ windows, during which external environmental processes operate to change the phenotype, may also be unduly restrictive. For the development of neural systems, e.g. the visual cortex, such critical periods are indeed circumscribed during the neonatal period. Yet, for most systems a degree of plasticity and flexibility operates on a much longer timeframe - even contributing to the variation in the decline of function during ageing, for example.

As new research adds to the evidence for intergenerational, and possibly transgenerational, passage of epigenetic marks, consideration of the significance of environmental epigenetics across a range of timescales, from the development of an individual to the evolution of a species, is necessary (Kuzawa & Thayer, 2011). At every level on this spectrum, there has been much less research into continued plasticity and the reversibility of epigenetic marks - rather than the induction of epigenetic changes. The revival of attention to Conrad Waddington’s ‘epigenetic landscape’ model has reinforced simplified views of the gene/environment, nature/nurture dichotomies being synthesised by environmental epigenetics: Waddington’s model is often used to illustrate the effect of distinct influences operating on the phenotypic outcomes of a genetic programme. Whilst Waddington did indeed consider the canalization processes in this landscape as operating to restrict the influence of external influences on the genome, in fact his model was more holistic, with the ‘landscape’ less a fixed entity and more a flexible surface like a tent, supported by poles and guy ropes attached to pegs. Any change in tension of one rope would produce shifts across the whole canvas. Thus, environments do not simply alter individual development by determining which valley an individual enters, but by altering the conformations of the valleys themselves. We feel that this conceptualization better captures the ways in which social and cultural factors alter biological processes, life trajectories and health.

***Deterministic Reasoning and the Risk of Social Stigmatization***

The two trends described above might interact to create another challenge as epigenetic reasoning enters broader societal discourse: the risk of social discrimination based on the assumption that certain individuals might be ‘epigenetically damaged’ by their (early) life experiences or exposures. This is a topic that deserves specific attention as a range of studies in environmental epigenetics focus their attention on socially pre-defined subgroups in society, particularly adults and children in low SES households, and also ethnic minorities or survivors of specific forms of early life trauma. This focus may be expressed in a number of ways; in sampling these groups directly for cohort studies; using such attributes as variables in experimental designs; or explaining assumed group differences in human society through simple reference to findings in model organisms or through comparision of studies in model organisms with human studies in other disciplines (e.g. psychology). In this context, deterministic readings of epigenetics, as discussed above, may create the impression that individuals, their health and their behavior are bound and ruled by the epigenetic marks they have acquired in early life. Such a perspective is problematic for a number of reasons. In these presentations, an individual’s behavior often appears as primarily determined by their biology.

For example, a British webpage[[1]](#endnote-2) about health during and before pregnancy supported by researchers from a number of renowned universities and featuring epigenetics prominently, includes a video narrative about a young man recently released from prison. In the video, his difficulties in school and working life and his criminal record are explained as potential outcomes of his mother’s stressful pregnancy and her failure to provide enough ‘warmth’ as a single parent in a tough living situation. “Charlie wasn’t born a criminal”, the narrator suggests, “but research suggests that his time in the womb and his early life could have made his behavior more likely. […] Maybe if Charlie’s time in the womb had been different, he had been different, too.”

Such simplified narratives – that are in no way supported by social or biological data – may easily stigmatize individuals who have experienced hardship in their early life as they suggest that they tend towards socially problematic behaviours. Social justice activists in the U.S., who mobilize epigenetic research and related studies on brain plasticity in early life to advocate for reforms in the school and juvenile justice system, frame such a determinist perspective as one of the greatest dangers to successfully using novel biological insights for improving the situation of young individuals from difficult homes. They fear, for instance, that such renderings of what environmental epigenetics can say and know about human psycho-social development might already be contributing to the limited availabity of parents willing to foster children from difficult households, since such a deterministic perspective suggests that they are ‘damaged’ in lasting ways that could not be ameliorated by the environment provided by a foster family. Representations of epigenetic findings on the effects of early stress, such as the above, commonly fail to recognise a significant body of relevant social science research, such as studies of social mobility and rehabilitation across the life course. This literature points to the importance of taking into account the effects of macro-economic structres, social relations in later life and opportunities afforded to disadvantaged individuals by different social institutions (Buffone, 2012). A failure to acknowledge the greater complexity of social life might lead environmental epigenetics to contribute, possibly unwittingly, to perspectives in society that frame poverty and social disadvantage as something that “replicates itself from generation to generation”[[2]](#endnote-3) through – as one Op-Ed in the New York Times put it – individual “brain architecture” rather than social conditions that are and can be crucially influenced by social and economic policies. It might also lead to the further stigmatization of individuals who had to flee war and oppression, and seek safety and possibly a new life in other parts of the world. This might be the opposite effect of what researcher hope to do: we know that many researchers in environmental epigenetics aim to contribute to positive social and biomedical change by rendering the embodied effects of unjust living conditions biologically visible. However, this might require greater interdisciplinary sensibilities in order to avoid the pitfalls of determinist and potentially stigmatizing perspectives.

**Conclusions**

As reseachers in environmental epigenetics and other fields of biology come to engage more with the social world and its effects on the body, health and disease, the social and political dimensions of their work inevitably become apparent. We suggest that researchers will need to enage actively with these matters in order to remain accountable for how their work contributes to certain visions of society and not to others. Environmental epigenetics holds the potential to help us better understand how social inequality and other differential exposures contribute to health and illness and can help focus social and political action to achieve more impactful societal improvements. On the other hand it can also be the basis for assigning undue blame to disadvantaged individuals or for increasing stigmatization.

How can we address this ambivalent potential responsibly? One important way is through interdisciplinary conversation and collaboration. Researchers in this group of authors have started to collaborate in order to bring both social science insights into the complexity of social life, and life science findings about epigenetic mechanisms to bear on novel experimental designs. Sarah Richardson and Heather Shattuck-Heidorn at Harvard University, for example, collaborate across the disciplines to study how not only physical sex differences, but also gendered life experiences (e.g. role expectations, sexism) shape difference in disease risk between men and women.

As biological research comes to address social issues and categories in experimental designs, it is important to recognise that expertise on social processes and structures is limited in biology. It is hence crucial that biological research draws on relevant expertise from the social science which can refine the formulation of research questions and suggest alternative interpretations of the findings. Systematic reflection is also important regarding the language that is being developed and used to report novel findings. Even if catchy metaphors like ‘programming’ might attract attention to a new research field, and claims about the relevance of ongoing basic research to human health and society can be important for acquiring funding, their social meaning and impact must be considered carefully. This implies a responsibility for funding bodies to reward cautious claims rather than overstatements and to support interdisciplinary collaboration that allows for sensible approaches to these important research topics. This is particularly crucial given the at the times troubled histories of scientific claims about the relationship of social structure and biology and the ways in which accounts of human difference can contribute to social stratification and discrimination.

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1. http://www.beginbeforebirth.org [↑](#endnote-ref-2)
2. [*http://www.nytimes.com/2012/10/21/opinion/sunday/kristof-cuddle-your-kid.html?\_r=0*](http://www.nytimes.com/2012/10/21/opinion/sunday/kristof-cuddle-your-kid.html?_r=0) [↑](#endnote-ref-3)