

## DOHaD in the Anthropocene

### Taking Responsibility for Anthropogenic Biologies

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#### 29.1 Entering the Anthropocene

As this volume has shown, the ‘developmental origins of health and disease’ framework (DOHaD) inquires into health and disease in adult human life as a function of environmental factors acting upon the human organism prior to conception, ante-/perinatally, in early life, and increasingly also throughout the lifecourse, respectively [1]. In its current form, which has been developed over the last three decades, it has not only helped to address the temporal and environmental dimensions of human disease aetiologies. This predominantly biomedical – in the broad sense of the term – framework has also proved useful to the social sciences and humanities to think through questions of human–environment relations, embodiment, and the role of the material environment in understanding ‘development’. The preceding sections in this volume attest to this generative role. They demonstrate how the framework acts as a boundary object, that is how it mediates between distinct disciplinary cultures. It also, however, carefully sensitises scholars to significant theoretical commitments, implicit assumptions, and practical consequences of current research on DOHaD conducted in these different disciplinary traditions. Many of these commitments are neither universally nor uncritically shared across academic disciplines. Attending to these differences is an important process in the development of DOHaD research.

In this final contribution to the volume, I want to look ahead and provide some tentative ideas about how the DOHaD framework might be translated into the Anthropocene. I understand the Anthropocene as the geological epoch following the Holocene and characterised by the acknowledgement that human action has developed into a formidable force shaping the planet in its entirety. More specifically, human action has been structured by the world’s dominant political economies into patterns of living and working that put immense pressure on the planet. So-called ‘planetary boundaries’ have been calculated that help to make visible how the planet responds [2]. These boundaries, such as climate, land use, biodiversity, ocean acidification, or the abundance of novel entities, have reached a point where the earth system might shift into radically different states that are likely to be far less amenable to human and social life than provided by the Holocene. Systems-speak aside, what this means is that deeply Western modern assumptions about progress, growth, and the stability of social expectations cease to exist as the unquestioned bedrock underpinning development and social welfare.

Today, tomorrow is less likely to be like yesterday. Instead, we are entering a phase of new extremes, new volatilities, and new non-linear dynamics and tipping points [3]. The Anthropocene challenges social and natural scientists to always also think in planetary

terms. The key distinction between local and global, which has shaped academia and politics for decades, needs rethinking. The 'terrestrial' has instead been suggested as a way of conceptualising all social-ecological action in planetary terms [4]. Whichever way one frames the issue, one key question remains: how can societies worldwide establish and sustain this planet such that humans and other species can continue to inhabit it? Or as anthropologists today phrase it: how can more-than-human liveability on this planet be achieved? [5] The notion of 'liveability' indicates that this is not only a question of biological survival for human societies and beyond. It is a question of what a decent life can be. Hence, it is fundamentally a political and ethical question that is today reposed under conditions of rapid planetary environmental change and resultant social-ecological struggle and suffering.

Addressing the challenges of more-than-human liveability is a vast field. I want to focus here on one aspect only, namely the need to understand biology as anthropogenic [6]. By that I mean that both human bodies and the environments they inhabit are deeply shaped by human actions and the political economies within which these actions are organised. The steep rise of non-communicable, often chronic, as well as infectious diseases and mental health concerns correlates in astonishing ways with Western industrialisation and the global rise of capitalist means of organising human co-existence [7]. Natural resource exploitation, expanding industrial production, and the creation and mass production of novel biological and chemical entities at an unprecedented rate characterise this period of unchecked progress and development [8]. The result is landscapes, bodies, and metabolisms that are shaped by the dominant patterns of economic exchange and their violent histories of colonial extraction. These are landscapes, bodies, and metabolisms that can be meaningfully understood only as human-made: anthropogenic biology.

How then can the DOHaD framework address anthropogenic biology? How can it contribute to more-than-human liveability on this planet and to emerging thinking and research on planetary health? I offer my tentative line of argument in three steps: first, I want to make more graspable the challenges of more-than-human liveability to the DOHaD framework. To do so, I briefly discuss developments in environmental epigenetics, microbiome research, and the emergence of planetary boundaries. All three developments demand cooperation between natural and social sciences. I believe that the DOHaD framework currently does not offer a unifying solution as to how to organise this cooperation. Hence in a second step, I outline three different modes of interdisciplinarity between natural and social science following the excellent work of Andrew Barry and Georgina Born [9]: service, integration, and agonism. In a final third step, I set out what I consider important research questions and perspectives in each of these three modes that address more-than-human liveability while retaining the key concerns of the DOHaD framework. I conclude that the DOHaD framework must take responsibility for the emerging politics of habitability.

## 29.2 Rethinking Origins and Development in DOHaD in the Anthropocene

In this section, I reflect on recent research on epigenetics, the human microbiome, and planetary boundaries to draw out the implications for the notions of 'origins' and 'development' in the DOHaD framework.

## 29.2.1 Environmental Epigenetics

Environmental epigenetics denotes the study of changes in gene expression that occur without changes in DNA sequence [10]. Such changes may occur in response to environmental challenges to an organism, including both material (e.g. nutrients and toxicants) and social factors (e.g. discrimination and adversity). They operate through a number of mechanisms. The three most important currently known are methylation, histone- and RNA- modifications. Some of these changes have shown to be mitotically and meiotically heritable, that is they may propagate across generations. Many of the specifics of this field and its implications for DOHaD have been discussed elsewhere in this volume. I therefore keep this point brief.

Epigenetic research challenges the developmental origins of Western biomedical thinking in Mendelian genetics, Weissmann's germ plasm theory, and – more broadly – the autonomous subject of Western modernity. If indeed heritable changes in germline functionality occur without DNA sequence change, individual human organisms are far more open to their past and present environments than so far appreciated. The DOHaD framework has begun to embrace these findings as they suggest mechanisms for phenomena that have so far only been shown through correlations [1]. The 'tracking' of physiological parameters over time from early life into adulthood might in fact be encoded at least to some degree in epigenetic processes. The details and some implications of this have been debated intensely over the last two decades. I want to focus on three lessons that follow from an epigenetics-inflected DOHaD understanding and that have received somewhat less attention.

First, 'environments' are diverse, dynamic, and never innocent. From my own fieldwork in a molecular biology lab working on environmental epigenetics, I have learned that epigenetic response mechanisms are far more subtle than the dominant digital logic of knock-out genetic thinking gives credit for [11]. Oftentimes, the handling of rodents in experimental settings appears to produce stronger epigenetic changes than the actual substance whose epigenetic effects were under investigation. This demonstrates that it might well be very difficult to isolate individual 'factors' or 'causes' from a complex environment. Instead, material and social factors readily interact in manifold ways with an organismic epigenome (if that term even makes sense), which is in itself a highly dynamic system. Mental models of human–environment relations derived from carcinogenicity and acute toxicity assume a unidirectional and non-reversible dose–response relationship between the environment and human organism (see Rossmann and Samaras in this volume). Epigenetics on the other hand suggests a reversible (e.g. *de novo* de/methylation) and perhaps bidirectional relationship where dose–response is likely to occur in a non-linear fashion; if indeed it is the right model at all. Lastly, environments are never politically and ethically innocent. The proof of principle experiments around the Dutch Winter Hunger cohort [12], the studies of licking and grooming behaviour under conditions of reduced nesting material and displacement [13], or the forensic psychiatric reconstruction of life histories in child abuse and suicide completers [14], all demonstrate that 'environmental factors' occur in politically, ethically, and socially charged settings that need to be appreciated in their economic, racial, and gendered complexity (see also the contributions by Meloni et al., Valdez and Lappé, and Cohen in this volume).

Second, while the notion of 'origins' in DOHaD was developed against genetic determinisms, it nevertheless still carries unwanted implicit remnants of Mendelian

and Weissmannian biological temporality. Origins suggests a starting point that is defined if not genetically then still by some kind of non-human nature. This might not be a blank slate, but it is a starting point that is often reified through methodological designs that rarely reflect the constructed and contingent nature of study subjects – be they ready-to-study mice or Romanian orphans. The dynamic environmental conditions that have evolved historically and cross-generationally – from nutritional environments to political regimes – are seldom explored in social-ecological detail. Epigenetics makes us attentive to these conditions and thus to the historical and social contingency of any starting point. ‘All the way down’ [15] in the body, we do not encounter some kind of pure biological matter. Rather the body is as much ecosocially entangled at the molecular level as it is at the organismic level. For ‘environments’, the scientific construction work and the ecosocial entanglements are even more obvious. Finding a plausible starting point for one’s research design is a question of cutting the network and making the cut accountable to the field [16], one’s own discipline, and scientific practice at large. Epigenetics thus helps to challenge the idea of ‘origins’ as a largely unreflected, somehow natural starting point of a developmental process.

Third, for all the attention to environmental factors, the notion of development centres the framework on the human organism. That is perfectly acceptable as it is a framework in human medicine. Epigenetics, however, shows the human organism to be remarkably open to its manifold environments. And *vice versa*: the human organism contributes to making its own livelihoods and niches. Most ecologists today subscribe to the idea that organisms do not find or adapt to existing niches but that organisms and environments interact in co-producing niches [17]. In social scientific terms, ‘niching’ as a material and social everyday practice might be the more apt analytic for these forms of world-making [18]. Perhaps, then, one ought to refer to ‘genealogies’ instead of ‘origins’ and ‘development’. This would help to address the multiple histories that run through any origin as well as the necessary contingency of multiple struggles of power/knowledge that mark any genealogy. Genealogies of Health and Disease: GoHaD?

Appreciating the multi-directionality of human–environment relations casts doubt on the developmental thinking in environmental factors, mechanisms, and linear causality for all but the most pervasive and drastic isolated health effects. Most human–environment interaction research, however, remains rooted in a thinking premised on distinct entities. It is either enviro-centric suggesting that the environment as an independent variable causes certain responses in the body or it is organism-centric and thus focused on how human action shapes the environment [19] or how humans may act as niche modifiers [20]. These are all entity-based ways of thinking about human–environment interactions. They start from entities with certain characteristics (organisms and niches) that enter into interaction. One might also, however, start from the action and investigate how action produces entities. This results in a process-based approach [21]. Drawing on the French philosophers Gilles Deleuze and Félix Guattari, British anthropologist Tim Ingold proposes to think of humans in environments not in terms of interacting entities but as ‘lines of flight’ [22]: ‘The line of flight, write Deleuze and Guattari, “is not defined by the points it connects, or by the points that compose it; on the contrary, it passes between points, it comes up the middle”’. What Ingold is essentially challenging his readers to do is think that humans and environments ‘should not be understood as interacting entities, . . . but as trajectories of movement, responding to each other in counterpoint, alternately as melody and refrain’. The result is

a process- or practice-based biology in which organisms and environments are constantly in becoming and in which development occurs rhizomatically rather than along a linear path. The notion of development in DOHaD does not usually take this into account. It rests on the understanding of an entity that is exposed to an environment as a set of factors. I am not suggesting that lines of flight readily translate into biomedical research designs. Yet they present an important conceptual challenge that sensitises researchers to the fact that evolutionary, structural, and systemic thinking never quite captures the situational specificities of human practice and its effects. These require process-based approaches.

## 29.2.2 Microbiome Research

The human microbiome denotes the aggregate of all microorganisms living on or in human tissue or fluids. Research efforts to better understand the components and dynamics of the human microbiome have rapidly increased over the last decade. The human microbiome comprises around 10–100 trillion symbiotic microbial cells per human individual [23]. They match if not outnumber human somatic cells, and their genetic material by far exceeds that of the ‘human proper’. Cells belong to around 500–1000 different species at any given moment within a human [24]. The genetic diversity and hence flexibility of this crowd by far exceed that of human genetic material. Over the last ten years, the field of microbiome research has begun to transition from the description of components to mechanisms and to the tentative development of clinical interventions. It has also invited a rich scene of lay ‘bio hackers’ to self-experiment alongside the emerging science with everything from probiotic foodstuffs to faecal transfer. A scientific understanding of how the microbiome impacts human somatic and mental health and disease onset and progression directly, as well as through complex interactions with the immune, endocrine, and nervous system, is only just emerging. Yet already today it is becoming clear that microbiome research will be another insult to human narcissism and anthropocentrism. After Copernicus, Darwin, and Freud, microbiome research demonstrates that ‘man’ is not even somatically speaking the master in his own house. While the skin as ‘philosophy’s last line of defense’ [25] remains intact if porous, inside that skin shell emerges a multiplicity of inhabitants and agencies in complex and finely balanced interaction and oftentimes symbiosis.

In the preceding section, I used epigenetics to question whether we should move from origins to genealogies and from development to lines of flight. Microbiome research extends this questioning. Anthropologist Myra Hird discusses how human subjectivity and social form need to be understood as also shaped by bacteria [26]. She demonstrates how deeply biological and economic notions of the self are enshrined in Western modern thought. Westerners think of themselves as individual cognitive agents that act autonomously, often in competition with each other to increase fitness. Society is often understood as synchronised individuals. The vast majority of biological and medical research designs presume the existence of human individuals who act autonomously and are structurally closed to their environments. The subsequent distinction between self and other (along the skin) is foundational to Western self-understanding. Taking bacteria and their actions seriously challenges this understanding. Hird focuses on the understandings of symbiogenesis and a very corporeal interdependence of human and microbial life. The human ‘I’ becomes a multitude or collective. Similar to Ingold,

she thus arrives at a world in becoming that is made up of encounters: encounters, for example, between humans and microorganisms that then develop ways of co-existing. Continuous encountering is what makes us what we are. Hence 'we' are not only epigenetically open to 'outside' environments, but 'we' are also open to 'inside' environments in the form of microorganismic collectives and their respective habitats.

It is this continuity of encounters that DOHaD also needs to address. Whether framed as contagion, as multi-species thinking, or as making kin, health and disease can rarely be sensibly understood as states of a single organism isolated in interaction from its environment. Dose–response simply does not capture the fact that exposure occurs in dynamic patterns of encounters. Even in the simplest scenario of an isolated single toxicant having an impact on a human organism, it is not only human cells and organs reacting. It is a symbiogenetically evolved social organism that responds. And while this social organism exhibits a distinct meta-stability that most people readily accept as human subjectivity, responses to substances are multiple and differentiated. Substances that occur at levels in the environment that are commonly considered well below toxicity thresholds not only interact to complicate exposure. They interact in differential ways with the human microbiome such that effects may occur that might well then surface as a human health issue. Hence environments are never really environments for only one organism as Uexküll suggested. The 'environment multiple' is a direct result of understanding the human body as a multiplicity of encounters.

### 29.2.3 Planetary Boundaries and Planetaryity

So far, I have addressed molecular, cellular, and organismic dynamics. Let me now briefly turn to planetary dynamics and how they might challenge DOHaD. Earth system science is understanding with increasing certainty that the planet's capacity to sustain life as we know it has boundaries that we are already transgressing through human action [2]. Environmental factors are thus ceasing to be local phenomena and instead need to be contextualised within planetary environmental change and its manifold repercussions for social-ecological systems across the globe. Philosopher Bruno Latour rightly challenges us to develop across all forms of scholarly activity a consciousness for the fragile and restricted conditions of habitability of the earth and life on it [4].

This planetary dimension challenges the DOHaD framework to understand 'the environment' and its health-relevant factors as part of earthly subsystems and its associated complexities and non-linear dynamics [20]. Major efforts have been underway for some years now to better understand and quantify both the global burden of disease [27] and the bio-geo-physical and increasingly social dynamics of earth's subsystems as well as their stable state boundaries [2]. Suggestions are being made to integrate earth system science and global health through international consortia and (big) data approaches [28]. Such approaches are commonly shaped by systems thinking and various forms of computational modelling that foster data-driven integration. The rise of earth system modelling from the late 1980s onwards has undoubtedly been an amazing process of knowledge production culminating in the 6th Assessment Report of the IPCC on the 'physical science basis' of global climate change. Never has a comparable global evidence machine been built of such scale and with such rigour. This evidence machine runs on a positivist epistemology that addresses 'the planet' through data aggregation and integration as part of system dynamics modelling. Its

dominant if not its only mode of speaking about large phenomena (aka ‘the planet’) is through scaling up by means of data aggregation and integration. Everything else is anecdotal or an opinion, that is not considered evidence. This approach aligns well with the data-driven calculations of global burdens of disease and exposomes.

Yet feminist literary theorist Gayatri Spivak [29] and others use the notion of ‘planetarity’ [30] to point to the data-driven construction of the planet asking where this leaves significant differences in ways of thinking and being on this planet – differences to which the social sciences and humanities attend. An altogether different perspective on this new planetary dimension is thus possible and important. The social sciences and humanities have long developed conceptual and empirical alternatives to address large-scale phenomena such as globalisation. Thinking in scapes and flows [31], global assemblages [32], global entanglement [33], and post- and decolonial critique [34] approaches ‘the global’ very differently. These approaches start from significant social differences and ask how they spread, reach, infect, travel, transform, and resonate. These approaches either focus on the forces that make phenomena graspable as ‘global’ or they move around inside the phenomena understood as global, showing their heterogeneity and multiplicity. Globality is about differences and what these differences (can) mean for respective others. Planetarity, in contrast, is often about trying to produce the one true representation of a whole. Of course, globality has been concerned with primarily social dynamics, while planetarity is rooted in biogeophysical phenomena. In the Anthropocene, however, this neat division of labour is being challenged as social inquiry becomes interested in material dynamics and ontological questions, while modellers of physical systems are incorporating not only economic exchanges into their models but increasingly also social dynamics.

Latour’s ‘Terrestrial’ [4] might be a useful point of contact between these very different ways of addressing phenomena that span the world in various ways. It is these reconfigurations of socio-material relations and the ensuing debate of how to address them that form the context within which the DOHaD framework can make an important contribution. How do we conceptualise ‘environmental factors’ when they cease to be local phenomena; when we try to understand them within a terrestrial context? One response would be to scale ‘environmental factors’ up, for example, to produce global estimates of ‘novel entities’, that is ‘new substances, new forms of existing substances and modified forms of life’ [8], and assess their impact on earth’s subsystems. Microplastics, lead, or persistent organic pollutants serve as examples. This might be related to the global burdens of disease in a data-driven integrative approach. In a very different approach, one might contextualise ‘environmental factors’ in highly political patterns of exposure related to colonial and racialised histories of exploitation and production, imperial debris, and the ruins of capitalism [35].

The Anthropocene and its demand to think in planetary terms, then, challenge biomedically and epidemiologically established notions of environment, environmental factors, exposure, dose–response, temporality, and scale. These notions are also embedded within the DOHaD framework. However, the framework does not inherently offer a singular and straight path to address these challenges. It is not a foregone conclusion that these challenges will be solved with data collected and analysed in the empirico-analytical frameworks of twentieth-century biomedicine. Rather, the DOHaD framework might afford a reflexive moment, a moment of producing ‘theory out of science’ [36], which might enable a diverse set of approaches to address anthropogenic challenges and to

address more-than-human liveability on a fragile planet. The DOHaD framework might offer a space within which data-driven approaches might complement other approaches that open up environments to a politics of exposure and habitability and that understand the human body as historically shaped, socialised, and habituated in patterns of practice [37]. Realising this potential and situating DOHaD in this sense, however, requires a diversity of approaches.

## 29.3 Modes of Interdisciplinarity: Ecosocial Co-laboration

### 29.3.1 Three Modes of Interdisciplinarity

Moving DOHaD into the Anthropocene cannot be achieved with a single logic or methodological approach. It would be a futile task to try to develop an overarching framework that can fully integrate the existing conceptual and methodological diversity, the desire to reduce and explain with the need to contextualise and interpret, and the strengths of rigorous data-based analysis with the strengths of critical inquiry. The present volume features this diversity, and it is clear that this does not cohere in an overarching heuristic or integrative framework – nor should it. Instead, it might be useful to distinguish between different forms of interdisciplinary engagement and forms of collaboration to give orientation and take away some of the pressure towards integration.

Andrew Barry and Georgina Born [9], drawing on their investigation of using ethnography within various other epistemic cultures, usefully outline three modes of interdisciplinarity: subordination–service, integration–synthesis, and agonistic–antagonistic. In the subordination–service mode, the research question and design come from one lead discipline, while the other discipline delivers additional data to extend or deepen the analysis. This is a fundamentally asymmetrical approach shaped by one discipline. In the integration–synthesis mode, two different disciplines readily find ways of addressing problems that are of interest to both. Biochemistry is the typical example within the natural sciences. It is a little less obvious across the natural/social science divide. This approach is symmetrical with both disciplines staying within their comfort zone but addressing a new topic in a shared way [3]. The agonistic–antagonistic mode is perhaps the most demanding. It arises when two disciplines differ in their understanding of the research object. Often, this disagreement is ontological in nature. For example, human differences might be considered a material and bodily phenomenon by biologists while social scientists would insist on it being primarily a social phenomenon constructed through the social interaction of subjects positioned in social space. In an agonistic–antagonistic mode, these differences between disciplinary perspectives are not levelled. Instead, they need to be worked with to turn them into something generative from which both disciplines can learn without necessarily agreeing to the respective other perspective. This approach is symmetrical but not as comfortable as in the integration mode. It is about letting oneself be irritated by other ways of thinking and designing research and by sustaining significant differences to learn and develop one's own perspective.

In opening up DOHaD further to social science thinking, this form of agonistic interdisciplinarity will play a key role. It is important to note that co-laboration [38] is possible: co-laboration is temporary joint knowledge production between two disciplines without necessarily having a shared goal. Two scholars from different disciplines might work together without necessarily getting a shared result. Rather they might take



different results and insights away from the co-laboration and integrate those into their respective disciplines. To make this rather abstract typology of possible interdisciplinary research more tangible, I want to briefly sketch examples of research questions and designs for each of these three modes of interdisciplinarity that might help the current DOHaD framework embrace the challenges of the Anthropocene.

### 29.3.2 Subordination–Service

Environmental epigenetics offers an obvious entry point for subordination–service interdisciplinarity. Currently, research within the DOHaD framework tends to operationalise environmental factors as independent variables, for example social disadvantage, zip code, and nutritional status (cf. Liz Roberts in this volume). For many social situations and structural inequalities [39], such operationalisations are not only too crude. They also miss the entire dimension of subjective and collective experience that social science would consider fundamental to the emergence of ‘the social’ and thus to pathways from ‘objective’ disadvantage to actually ‘living inferiority’ [39] and associated individual bodily health and disease. Hence social science could contribute its understanding of social dynamics to research on social drivers within the DOHaD framework. At a time where many countries – and in particular the major metropolises – are undergoing fundamental transformations trying to meet climate targets, this kind of social science service work could also contribute to making sure that ambitious climate targets are not reached at the expense of increasing inequality and thus worsening individual and public health outcomes.

Subordination–service approaches might also work the other way around. The long-term social inquiry into living with chronic respiratory diseases, for example, might benefit from global to local climate projections, air quality modelling, and associated health data. The Anthropocene foregrounds the dynamics of nature–culture relations, making such social inquiries into ‘natural’ phenomena such as disease aetiologies even more relevant [40]. Planetary health is currently conceptualised largely in biomedical and public health terms with the social sciences adding knowledge about social dynamics. This could be – perhaps ought to be – turned around placing well-being and environmental justice at the centre and putting the medical disciplines in the service role.

### 29.3.3 Integration–Synthesis

Recent work at the interface of sociology and biogeochemistry presents an outstanding example of biosocial interdisciplinarity in the integration–synthesis mode [6]. Hannah Landecker, a sociologist and historian of science, and Cajetan Neubauer, a biochemist, in rather serendipitous fashion, began to work on the planetary availability and bodily effects of methionine together. Methionine is an essential amino acid, that is it cannot be synthesised by the human body and needs to be taken up through food. Working together on the methionine metabolism both globally and within the body, the two perspectives together were able to ‘establish the scale and historical trajectory of the methionine industry and provide a preliminary model for tracing this amino acid through the food supply into the human body’ [6]. The study shows how planetary-scale anthropogenic activity changes ‘environments’ and consequently also human metabolisms with so far largely unknown consequences. Human biology and ecology, that is both environment and body, are understood as anthropogenic. The DOHaD

framework thus requires biosocial, or rather ecosocial, collaboration as it is the social science perspective that can reveal how environmental factors come to be what they are through anthropogenic activity, specifically through analyses of dominant political economies and ecologies.

Hannah Landecker reflects on the back of the methionine study: ‘I have always felt that my contribution has been to enable the asking of experimental questions, the parameterisation of models, and the forming of hypotheses that would not otherwise have been possible . . . What Harry Collins termed “interactional expertise” has also been important in helping teams of different kinds of knowledge practitioners recognise ways in which they don’t understand one another, or facilitating the synthesis of different modes of proof or reasoning. . . .’ [41] Landecker reports her interdisciplinary research as an example of integration–synthesis cooperation, that is both disciplines, biochemistry and history, contribute from within their comfort zone to arrive at a new question and analysis. This is cleverly done, and it is this approach that enables Landecker to conduct a historical and social study of chemicals of metabolic significance – as a social scientist, albeit one with deep knowledge of natural science and the dynamics of the particular field in question.

### 29.3.4 Agonism–Antagonism

Oftentimes, however, social science perspectives do not readily complement or integrate with existing natural science or medical knowledge. Take approaches to social dynamics as an example. Biomedical or public health operationalisations of social dynamics often do not resonate with state-of-the-art social scientific knowledge and critique. The reason for such dissonance often lies in profound differences in the understanding of the research object. Much medical expertise works with a concept of ‘the social’ that is based on individuals interacting within a value system or culture. The notion of the individual tends to be under-socialised, that is based on ideas of individual decision-making that might be found in behavioural economics. Whereas the notion of the ‘value system’ tends to be over-socialised, that is assuming a firm grip of an abstract but homogeneous set of values on the framing of individual behaviour. Social dynamics from most social science perspectives sit in between these two perspectives and often work with notions of agency, subjectivity, and practice that combine structural (‘value system’) and individual (‘decision-making’) elements in highly dynamic and reflexive ways.

The agonistic–antagonistic approach starts from such dissonances and tries to make them generative. Agonism here refers to the work of political scientist Chantal Mouffe, who argued for agonism as a democratic form that does not solely rely on consensus but rather is able to work with differences as a potentially positive democratic force. Agonism within interdisciplinary research then means working with and through differences rather than searching for an integrative framework. This takes some work between the right partners. Working with differences requires explicating methodological, epistemological, and ontological assumptions. Differences need to come out to enable research that searches for common ground while critically reflecting on one’s own disciplinary perspective.

In this regard, the DOHaD framework needs to address the question of how much it can allow environments and bodies to be ‘situated’ in a social science sense [42]. As it stands, DOHaD often rests on a universal body that responds to environmental factors.

While this rests on a perfectly plausible set of assumptions, it does appear to underestimate what anthropogenic biology means. If all-pervasive anthropogenic activity has begun to change environments and bodies in significant ways, the ‘universal’ body is perhaps not the most prudent assumption anymore. Of course, at some general level, most bodies share some basic structures and processes. Yet these structures and processes are shaped by widely different trajectories through individual life histories and start to differentiate in significant ways. Most study designs assume a universal body and investigate the response to exposure. Yet ‘exposure’ to chemicals, social disadvantage, infrastructural violence, and to colonial legacies is systematically patterned and has been so for many centuries. The ‘inward laboratory’ of the body adjusts and contributes to these patterns and to living in, with, and through these patterns in significant ways. Rather than starting from the universal body at a national or even global scale, is it not high time that we should also try to scale approaches a little differently? Sure, trying to assess the global burden of disease, the global presence of chemicals and novel entities, and planetary boundaries remains important. Systems thinking and data-based integration remain important, and attempts at measuring the exposome and conducting exposome-wide association studies will certainly be productive in many ways even if they are bound to never reach their objective [43]. Yet other exposure patterns also matter. We might start with landscapes and how they have been shaped by political histories and economies, social dynamics and forms of dwelling, as well as biogeophysical contexts of climate, topography, and ecology. Urban and rural landscapes [5] can be investigated in great ecosocial detail to better understand how they afford particular exposure patterns and how these contribute to shaping deeply situated bodies [44]. Inside such landscapes, situated bodies are thoroughly historicised, socialised, and politicised and constantly in becoming. They are not simply local as they relate to many transnational exchanges and flows of people, goods, and information as well as planetary environmental change. Such ecosocial analyses of the situated genealogies of health and disease require the agonistic and antagonistic struggle between critical social science perspectives and rather more solution-oriented medical perspectives.

## 29.4 The Future of DOHaD: Taking Responsibility for Anthropogenic Biologies

Translating the DOHaD framework into the Anthropocene requires an opening up of its underlying biomedical and epidemiological thought style. It needs to be opened up, because the human body and the complex social-ecological environments within which it dwells can only be understood as anthropogenic. They have ceased to be ‘natural’ in any meaningful sense. In an epoch where human action and its political economy are thoroughly transforming life at a planetary scale, the material agencies of more-than-human liveability cease to be universal and innocent – if they ever were. Situating bodies and environments is one response. Situating means understanding how ‘environmental factors’ are embedded within landscapes that are shaped thoroughly by land use practices and metabolisms reflecting dominant natural, social, and moral orders. And it means appreciating the habituated nature of the human body-in-practice that fends for its livelihood in such landscapes.

The DOHaD framework offers sufficient openness to pursue health and disease in emerging and dynamic patterns of everyday practice. The key to such an approach is the constant careful calibration of a balance between on the one hand appreciating the

singularity of life as such [45] and its multi-species encounters and on the other recognising structural continuities in life itself [46] shaped by hegemonic patterns of bio- and geopolitics regulating bodies and landscapes. Methodologically, this has to be a programme that starts from an in-depth understanding of the regularities and patterns that shape health and disease over time in situated cases. Long-term social-ecological field sites that can understand exposure as practice rather than correlation seem promising. Ethnographic, micro-sociological, and micro-historical approaches need to be brought into conversation with, on the one hand, biomedical and epidemiological methods and, on the other, with methods that can assess drivers of landscape change, for example earth observation, land use science, and climate impact modelling. Such multi-method approaches need not be fully integrated into a single framework. They can explore the tension between the singularities and regularities of more-than-human liveability by exploring both statistical and analytical generalisation; by situating numerical models of social-ecological dynamics; and by deconstructing knowledge claims but also by reconstructing alternatives.

Starting from situated cases and possibly community-based research into more-than-human liveability also offers the chance to embrace the necessarily political nature of this work. Long-term multi-method field sites offer the opportunity to align knowledge production with the co-production of interventions rooted in a thoroughly situated understanding of the developmental origins of multi-species health and disease. In such an approach, the DOHaD framework begins to take responsibility for how bodies and environments are known and problematised. It begins to take responsibility for the worlds people live in and for possible futures.

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