Biochemical Scale

Andrew Barry

University College London

HUMANIMALIA 16.2 (Summer 2026)

Abstract: The scale of global meat production is vast, but how is its scalability achieved? This essay addresses this question through a response to Dinesh Wadiwel's analysis of the gestational and metabolic labour of animals. While valuing his focus on labour, I argue that an account of the scalability of meat production also needs to attend to the biochemistry of metabolism as well as its industrialization. Following the work of Maan Barua and Hannah Landecker, the essay zooms in on the critical importance of methionine supplement to poultry feed in forging relations between the biochemistry of the chicken's body and the wider circuits of an industrialized metabolism.

Keywords: *metabolism; scale; animals; biochemistry; methionine; urban*

Bio: Andrew Barry is Professor of Human Geography at University College London and co-convenor of UCL Anthropocene. Andrew studied chemistry and the history and philosophy of science as an undergraduate, and previously taught at Brunel University, Goldsmiths, and Oxford University, before joining UCL. He is author of *Political Machines: Governing a Technological Society* (Athlone), *Material Politics: Disputes along the Pipeline* (Wiley-Blackwell), and co-editor of *Interdisciplinarity: Reconfigurations of the Social and Natural Sciences* (Routledge), *Chemical Exposures: Toxicity in the Anthropocene* (UCL press, forthcoming) and *Carbon Times* (Duke University press, forthcoming).

Email: a.barry@ucl.ac.uk

ORCID: 0000-0002-7632-9334

Humanimalia 16, no. 2 (2026): 167–180. DOI: 10.52537/humanimalia.28280

"The living world is not amenable to precision-nested scales" declares the anthropologist Anna Tsing, subtitling an essay on what she terms "nonscalability". At first reading, this declaration is puzzling. After all, as Dinesh Wadiwel observes, the scale of global meat production is vast, resulting in the slaughter of eighty-three billion land animals in 2022. The commercial producers of meat have surely been very successful in making the living world amenable to scale. But the puzzle appears to be resolved by Tsing herself, who goes on to define not scale, but scalability. Scalability, she proposes, refers to projects that "can expand *without* changing".[1] This qualification is significant for it draws attention to the multiple ways in which nonhuman animals change and are required to change in order for meat production to be made scalable. Scale has often been conceived as a series, as if one scale is merely an expansion or a magnification of another. But if larger scales are understood not as replications of smaller scales, but as the effect of scalability, then a question arises. How is scalability achieved?

Dinesh Wadiwel's answer to this question in his paper focuses on what he terms the metabolic labour or, "more narrowly", the gestational labour that nonhuman animals are required to perform. It is through the gestational labour of animals that the problem of scalability is resolved, for "the reality [is] that today mass scale forced gestational labour is required by a huge number of animals in food systems".[2] Artificial insemination is used to maximize the efficiency of the reproductive process, and infant animals are separated from their parents, reducing the lapse of time between periods of pregnancy.[3]

Wadiwel's focus on gestational labour is critical for two reasons. First, because it highlights that the primary function of the female animal, from the point of view of the industry, is to reproduce. In consequence, it becomes essential for the industry, if it is to achieve

1 Tsing, "On Nonscalability", 507. Emphasis added.

2 Wadiwel, "Industrial Scale Surrogacy", 150.

3 Wadiwel, *Animals and Capital*, 102.

scalability, to govern the timing and frequency of reproduction, in this way achieving the "subsumption of gestation into the rhythms of capitalism".[4] Second, the concept of gestational labour makes clear that gestation is a critical part of the labour process, which is distinct from, yet depends on, the "metabolic labour" of nonhuman animals. In this industrial context, surrogacy becomes the norm, "a mainstay structuring reality", in which all animals "will experience forced separation from the animals who performed the gestational labour that produce them".[5] The political challenge, for Wadiwel, following Sophie Lewis, is whether it is possible to imagine a society of animals and humans in which "mass forced gestational labour" is no longer performed or considered, or is successfully resisted.

Placing gestation at the heart of an analysis of scale and scalability is persuasive, but it raises further questions. One concerns the relation between metabolism and gestation. In Wadiwel's account, metabolic labour and gestational labour are conceived as two distinct but connected forms of labour that nonhuman animals perform. Gestational labour is necessary for the continual supply of animals for dairy and meat production, while the function of metabolic labour is to "transform the body of this animal into a product".[6] However, as Hannah Landecker has suggested, a "deep trench" between the concepts of metabolism and gestation cannot be assumed. As Landecker observes, "food is generally understood to provide the stuff out of which bodies are made, to provide important cofactors and essential nutrients and the energy that bodies need".[7] In practice, however, food also changes "the operation" of the body, including the process of gestation. In this view, food is understood to be more than a source of energy: it is also information. Second, and relatedly, Wadiwel's analysis dwells on the scale of the animal body and not on what he terms, following Les Beldo, the extent of the "microbiological changes"[8] that occur to the animal body before, dur-

4 Wadiwel, *Animals and Capital*, 104

5 Wadiwel, *Animals and Capital*.

6 Wadiwel, *Animals and Capital*, 107.

7 Landecker, "Metabolism".

8 Wadiwel, *Animals and Capital*, 101.

ing, and after gestation. Seen in this light, Wadiwel directs us to the critical importance of gestation in the scalability of meat production, dwelling on how this is operated on at a physiological scale, for example, through artificial insemination and the separation of the infant from the adult animal. His attention is directed outwards, from the individual labouring animal body to the system within which this nonhuman animal lives. But, in doing so, he says little about the biochemical changes to the animal body that are also critical to the scalability of animal lives.

In these terms, Dinesh Wadiwel's emphasis on the physiological scale of gestation is complemented by the work of the geographer, Maan Barua. Whereas Wadiwel's interest is in the labouring body within the system of production, Barua asks us to consider the biochemical changes to the body of the animal, and its metabolism, before working outwards to address the organization of the metabolic system of which the individual animal is a part. In his analysis of metabolism, in relation to chicken farming in urban India, for example, Barua dwells on the movements of — and the movements through — the individual chicken: the city moves through the body of the chicken, as much as the chicken's body moves through the city. These are movements which "reveal how urban ground is fractal: loam and silt mixed with household garbage in one place, compacted earth with pieces of broken concrete from a city under continual construction at another".[9] In this simple choice of perspective and scale, the chicken is not treated as a typical example of a species, but as a body that is traversed by multiple flows that it both generates and encounters. And in this incessant movement and transformation, multiple scales come into view. The scale of the city, of course, and its wider economy, and the sheer quantity of chickens that both live and are consumed in the city. But the focus on the chicken's motion also directs us towards the microspaces of the city, and the urban fragments "under continual construction", that both enable and channel its everyday life: "the birds' foraging sutures different urban fragments to compose an urban barnyard,

9 Barua, "Metropolis and Metabolic Life".

one that emerges without a model but also without mere chance".[10]

The idea of metabolism lies at the heart of Barua's wider project.[11] Conceptually, as Barua himself observes, metabolism points in two directions. The first is to the development of a tradition of thought, on urban metabolism, in urban studies, political ecology and human geography, which draws inspiration from Karl Marx's brief discussions of metabolism [*Stoffwechsel*] in *Capital volumes 1 & 3*. For Marx, the idea of the metabolic process, adapted from the work of the chemist Justus von Liebig, becomes a way of conceptualizing the relations between labour and the productivity of nature. Given the concentration of labour in the industrial city, and the consequent demand for food which the city itself cannot produce, a metabolic relation consequently emerges between the city and the countryside, which feeds it. At the same time, the productivity of rural land is progressively intensified in order to address the growing demand of the urban population: "with the development of natural science and agronomy, the fertility of the land itself changes, since there is an alteration in the means by which the soil's elements can be made capable of immediate exploitation".[12]

In this context, metabolism is necessarily structured by class relations, gender, and caste in Barua's work. Yet while Barua is clearly in dialogue with this tradition of thought on metabolism in urban theory and political ecology, which directly informs Wadiwel's account of metabolic labour, he also aims to contribute to a different conversation, which is arguably also suggested by Marx's reading of Liebig. This is the conversation between the social sciences and chemistry, and biochemistry in particular. This is Barua's second direction. In this conversation, the work of the historian of science, Hannah Landecker, is a critical mediator between the social sciences and contemporary biochemistry. For while the dominant literature on metabolism in urban studies is broadly concerned with the commodification and transformation of nature, which occurs externally

10 Barua, "Metropolis and Metabolic Life".

11 Barua, "Metabolic Politics"; "Metabolic Geographies"; "Metabolic Ethnography".

12 Marx, *Capital, Volume 3*, 904.

to the human body, it has very little to say about metabolism as a biochemical process, or indeed about the differences between von Liebig's understanding of *Stoffwechsel*, and biochemical accounts of metabolism today. By contrast, Landecker traces the flows generated by the industrialized agrifood system *through* the human body, dwelling on the evolving work of the claims made by the chemical and food industry as it progressively develops new and more profitable forms of food for human consumption.

If Marx and, later, Foucault were interested in the ways in which workers' bodies were shaped "externally" — through the organization of the working day and the division of labour, and through discipline — Landecker and Barua address the ways in which the progressive transformation of agricultural and food production generates internal transformations in both human and nonhuman bodies. Landecker is alert to the chemical transformation of food, which increasingly contains chemical substances that are of little to no nutritional value and, indeed, stretch the meaning of what we understand to be food. For Barua, there is a shift from the "anatomo-politics of disciplining bodies" to a metabolic politics. This metabolic politics becomes "non-hylomorphic for it has to do with acting on the body's capacity to transmute materials and, therefore, works with the variations of materials and forces".[13] Like Gilbert Simondon, who was fascinated by crystallization as a process of transformation generated from within,[14] Barua and Landecker invite us to consider metabolism as a process that can be traced at a biochemical scale. This approach is in contrast to Wadiwel's, who addresses metabolism at a physiological scale through the prism of the capitalist labour process.[15]

Given this focus on metabolic politics, I want to zoom in on Barua's brief observations about the biochemistry of metabolism and, in particular, the critical importance of one amino acid, methionine, which

13 Barua, "Metabolic Politics", 6.

14 Simondon, *L'Individuation psychique*, 62.

15 My thanks to Hannah Landecker for her insightful comments on an earlier draft of this paper and, in particular, for noting the importance of the relation between the biochemical and the physiological, which is not "seamless" (Landecker, personal communication).

is added to poultry feed. Although chickens feed on soy and rice, these do not in themselves enable chickens to grow well. As was recognized as early as the 1940s, methionine is an essential amino acid that must be derived from food.[16] Indeed, methionine has a particular importance because it "is the initiating amino acid for protein synthesis" and, therefore, for growth. As Barua observes, "methionine enables converting soy and maize into animal biomass, thus speeding up metabolic work or the transformation of feed into bodily protein".[17]

As an essential amino acid, methionine is contained in any healthy diet. It is not a medical antidote to a disease but serves as a supplement that makes up for the insufficient quantity of methionine that chickens, for example, might be able consume without the availability of this supplement. Its presence in animal feed is a manifestation of what Landecker has termed the "industrialisation of metabolism". When writing about metabolism, following Liebig, Marx was preoccupied with the transformation of the soil and its productivity. By contrast, for Landecker and Barua, it is the production of molecules essential for metabolism, such as methionine, that has been intensified, not just the production process that generates the soy and rice on which chickens feed: "because of its relatively low cost and the efficiency of using calibrated mixtures of amino acids instead of whole protein, there is a rapidly expanding worldwide market for synthetic methionine".[18] Indeed, the amino acid added to poultry feed is the synthesized product of the growth of the petrochemical industry: "Industrial-scale methionine synthesis [enabled by the petrochemical industry] has opened a way to bypass long-evolved ecological interdependencies by shifting the way that sulphur is assimilated and circulates through food webs".[19] In this respect, synthetic methionine is not unlike a host of pharmaceutical molecules and biochemical agents that are produced by the transformation of hydrocarbons by industrial organic chemistry. Unsurprisingly, much of the

16 Neubauer and Landecker, "Planetary Health Perspective", e560.

17 Barua, "Metabolic Geographies", 152.

18 Neubauer and Landecker, "Planetary Health Perspective", e561.

19 Neubauer and Landecker, "Planetary Health Perspective", e561. See also Barua, "Metabolic Geographies".

early literature on methionine from the 1930s and 1940s is not concerned so much with the *biochemical* function of the amino acid in the body. Rather, it focuses on the *organic chemical* problem of how to design a synthetic pathway that would transform hydrocarbons into methionine and that would work at an industrial scale.[20] The industrialization of methionine production, its *scalability*, therefore depends on the development of synthetic pathways, an organic chemical problem, the solution to which is not biochemical.

While synthetic methionine is not radically different from "natural" methionine that is not manufactured, there is one significant difference. Chemically, the synthesis of methionine produces equal quantities of both "right-hand" and "left-hand" forms (isomers) of the molecule, but only the left-hand form of methionine is found naturally and functions as a metabolite. In practice, the right-handed molecule is transformed into the left-handed form inside the body.[21] Nonetheless, legally, it remains the case that organic feed in Europe cannot contain synthetic methionine whereas, with some restrictions, US organic farms have been able to use synthetic methionine since 2003.[22] However, industrial synthesis enables methionine to be produced at scale, thereby intensifying meat production and consumption. In these circumstances, Neubauer and Landecker suggest that the potentially damaging consequence for human health is not because of the chemical composition of methionine itself, which is evidently not toxic, whether it is produced through synthesis or not, but because of the cardiometabolic risk of excessive meat consumption that the industrial production of methionine enables.

Barua observes that metabolism is both a scalar and a temporal process. On the one hand, he follows the urban metabolic process

20 See for example Livak et al., "Synthesis of dl-Methionine".

21 Many organic molecules including methionine are three dimensional structures that exist as distinct mirror images of each other and take left- and right-handed forms. Although different isomers of the same molecule have the same chemical composition, they may have different biochemical properties in the body.

22 Lindsay Fernandez-Salvador. "Methionine—History and Uses in Organic Poultry Production." *OMRI*, November 2023. https://www.omri.org/methionine-history-and-uses-organic-poultry-production.

to which methionine contributes through the city and to and from other regions where rice, soy, and methionine are produced.[23] The production of methionine enables the urban farmer to scale up the production of chicken, expanding the relations between the city and agricultural and petrochemical production at a distance. At the same time, the scale of poultry farming is intensified, even if it is also dispersed across the city. In this way, methionine forges connections between city and countryside, across the city, and between scales. It can be understood as what the historian Gabrielle Hecht calls an "interscalar vehicle".[24] But to understand the process of scaling up, we can also trace the metabolic process inwards, inside the pellets of feed to consider the structure and composition of the methionine molecule and its scalability. Whether it enters the human or animal body, the methionine molecule has the capacity to become scalable, to act as the essential part of a series of biochemical events. Methionine is evidently not the only chemical component of metabolism, but its presence is essential.

It is easy to imagine that methionine—as a distinct molecule that is administered in the form of a digestible pellet of animal feed—has the remarkable property of enabling the body's capacity to grow. Yet, as Evan Hepler-Smith observes in an analysis of toxicology, the idea that molecules act alone, in isolation, is not given by the nature of chemicals but is rather "the product of legal structures, administrative procedures, regulatory lists, information systems, and nomenclature conventions".[25] While methionine is non-toxic, a similar argument can be made about its biochemical efficacy. The delivery of methionine in such quantities, and in a concentrated form, depends on what Hepler-Smith terms the molecular bureaucracy of chemicals, which fosters a market for synthetic methionine in poultry production. Animal feed is not incidental to the life of methionine, but its delivery system. In turn, methionine requires its own chemical infrastructure that takes the form of a pellet of animal feed; a tablet that keeps the chicken healthy when there is insufficient methionine

23 Barua, "Metabolic Ethnography".

24 Hecht, "Interscalar Vehicles".

25 Hepler-Smith, "Molecular Bureaucracy" 534. See also Barry et al., "Chemical Exposures".

available from natural sources, such as worms. And further, at a molecular or biochemical scale, methionine serves as a scaffold that brings sulphur safely and efficiently into the animal's body. Indeed, it "is unique among indispensable amino acids due to its sulfur atom".[26] The city, for Barua, moves through the body of the chicken, but the products of the chemical industry, including sulphur, do too.

Moreover, metabolism is a temporal process. Of course, the industrialization of metabolism represents one feature of what Anthropocene scientists have termed the great acceleration of late twentieth century consumer capitalism, to which the petrochemical industry made a substantial contribution. But acceleration occurs at multiple scales: the production and consumption of meat is accelerated; the growth of chickens' bodies accelerates through the plentiful supply of amino acids; and the rate of metabolism is accelerated depending on the availability of methionine in the body. For agricultural scientists, methionine supplements may improve "feed intake, feed conversion ratio and average daily gain" in chicken.[27] Yet acceleration of feed conversion is not just a matter of processes occurring more quickly, but also of enabling production and consumption to proceed at a larger scale. As Landecker demonstrates, in an analysis of a radically different case (cryopreservation), slowing things down (or speeding processes up) is transformative: "recent demonstrations of effects of cryoprotectant exposure that are nonlethal [are] nonetheless profoundly impactful".[28] Similarly, biochemists and nutritionists address the transformative impacts of accelerated metabolism through their research on the relation between the presence or absence of methionine. Farida Tripodi et al. argue, for example, that methionine restriction is associated with an increase in the "inhibition of cell growth in different cancer cells, such as sarcoma, melanoma, prostate carcinoma, colorectal cancer cells in vitro, as well as in animal models".[29] In Barua's example, the chicken roams across the city, pecking at the sacks of feed deposited

26 Elango, "Methionine Nutrition", 2518S.

27 Pokoo-Aikins et al., "Effects of Feeding", 2.

28 Landecker, "Cell Freezing", 635.

29 Tripodi et al., "Methionine Supplementation", 2.

by the urban farmer.[30] But for many animals, methionine is delivered in precisely measured quantities in confined conditions, where the rate of growth is monitored, analysed, and optimized.

Perhaps one of the attractions of the concept of metabolism to urban theory and political ecology is that it has provided a neat way of cutting across the distinctions between the natural and the social, between the city and the countryside, and between political economy and everyday life. For political ecologists, the analysis of metabolism pointed towards the flaws in the Malthusian proposition that the productivity of the land could only grow at an arithmetical rate, whereas population could grow, if unchecked, exponentially: Malthus failed to recognize that agricultural production could be intensified through the application of chemical and agricultural science. Adding chemical supplements to the soil in the countryside contributes to the growth of the city. Indeed, from the point of view of many urban theorists, following Lefebvre, the countryside should not be considered as distinct from the city, but as an array of non-city territories that service the city's needs. Hence, "city-building processes within the fossil-based metabolic regime hinge upon the appropriation of unpaid work/energy from non-city territories and environments and the concomitant degradation and ruination of the latter through the crisis-driven dynamics of accumulation".[31] Wadiwel demonstrates that this metabolic regime, while dependent on fossil fuels, is also critically dependent on the metabolic and gestational labour of nonhuman animals.

Barua's own focus on metabolism supplements and complements these accounts in two ways. One is by shifting perspective from the physiology of gestation to the everyday life of the animal. Barua's second shift in perspective, drawing on Landecker, is to understand metabolism as a biochemical process, in which a range of molecules play their part. This shift to the biochemical and to a metabolic politics "illuminates nutrient pathways and cycles"[32] not just within the

30 Barua, "Metropolis and Metabolic Life"; "Metabolic Ethnography".

31 Brenner, "Planetary Metabolism".

32 Barua, "Metabolic Politics", 4.

city, but within the body too. In this analysis, the molecule, methionine, does not just operate at the level of the molecular. Rather, this specific structure, in the right conditions, forges relations between the interior of the chicken's body and the wider circuits of an industrialized metabolism. It follows that an analysis of the scalability of meat production must attend to its biochemistry.

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