

Urban Metabolism at UCL – A working paper

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Abstract

The concept of urban metabolism is increasingly used to explain urban ecological relations in different disciplines such as civil engineering, economics, planning and geography. In the summer of 2011, the UCL Environmental Institute funded a small project to explore whether urban metabolism, given the interdisciplinary vocation of the term, could be used as a concept to bridge perspectives and build collaborations across different strands of research on environment and cities. We carried out sixteen interviews with scholars in UCL who have engaged, directly or indirectly, with debates on urban metabolism. Qualitative analysis of the interviews revealed their coalescence around three broad interdisciplinary perspectives: the perspective adopting a **Functional Analogy** emphasises urban metabolism as conducting the functions that reproduce the city; the perspective adopting a **Form Analogy** uses the concept as a entry point into the internal configuration of the city; the **Dialectical Production** perspective emphasises urban metabolism as directing the production of urban economies and their distribution. In every case, words of caution were expressed about the limited potential of biological concepts to capture the complexity of social processes and urban life. However, urban metabolism emerges as a malleable concept which draws attention to the materiality embedded in urban relations and may open new avenues of discussion across disciplines.

Introduction

Debates and interventions on urban sustainability have been heavily influenced by concepts in ecology and biological sciences. One such concept is that of “urban metabolism”, which refers to the metabolic processes by which cities transform raw materials, energy and water into the built environment, human biomass and waste. The adoption of this concept has fostered new imaginations of what the city is and how material and immaterial flows – through infrastructure, through different economies – mediate the production and reproduction of the city, both as a biophysical and socio-economic entity. Urban metabolism has also inspired new ways of thinking about how cities can be made sustainable and has raised criticism about the specific social and economic arrangements in which some forms of flow, or being in flow, are prioritized within the city.

The concept has been influential across a range of disciplines linking urban studies with fields as diverse as engineering, human geography, economics and development studies. The research is now starting to make an impact in policy development and practice. For example, the Urban Unit at the World Bank released in 2009 a high profile report called *Eco2Cities*, which advocated urban metabolism understandings of the city in sustainable urban development. Yet, it could be argued that urban metabolism-inspired prescriptions have remained within single disciplines and they have not yet made a difference in terms of creating radically new ways of thinking about the city and its development.

Funded by the UCL Environment Institute (EI), the *Urban Metabolism at UCL* project was launched in June 2011 to foster interdisciplinary dialogue around urban metabolism. Rather than creating a shared understanding of urban metabolism, the project focuses on exploring the potential for interdisciplinary studies of the sustainable city by revealing the diversity of approaches and perspectives around this key concept within UCL and establishing links with the wider debate.

This initiative contributes to UCL’s work on sustainable cities, within the wider initiatives promoted by UCL Grand Challenges. The first phase of the project included three activities: 1) an initial ‘map’ of existing resources on urban metabolism and urban material flows across all the faculties in UCL; 2) a series of filmed interviews with key researchers on urban metabolism at UCL; and 3) a literature review to position current research at UCL within wider debates on urban metabolism. This paper provides a synthesis of the findings of the project so far and aims at mapping current thinking within UCL and to foster further interdisciplinary and creative dialogue and connections.

Mapping UCL Perspectives

A total of 16 interviews were conducted throughout the summer and spring 2011 with academic staff and research students at UCL, whose work is either directly or indirectly underpinned by the notion of urban metabolism. A qualitative data analysis software was used to explore the similitudes and differences between different urban metabolism discourses. The discussion that follows is based on what emerged from those interviews and should be read as a map of perspectives ‘under construction’ or, in other words, as a dynamic illustration of the variety of interpretations tapped so far within the UCL community.

The interviews revealed several points of commonality. First, most interviewees emphasised movement through space and time, change and transformation as fundamental principles configuring human activities and interactions in human settlements. In this sense, urban metabolism was often described as a useful means to reveal the material and historical basis of human nature interactions. Second, different metabolism- inspired analyses of the city highlight both the embeddedness of the material in social institutions and its agency to challenge those institutions. Finally, most interviewees expressed a note of caution in respect of the extent to which human-natural structures can be easily assimilated to biological ones. The concepts that are repeated in different accounts of urban metabolism are “flows”, which highlights movement as a constitutive element of urban life; “circulation” which focuses on the direction of those flows; “metabolic rate” and “regulation” which emphasise the measurement of change in those flows. However, there were also significant differences between the approaches mapped in relation to how the city is conceptualised, what is the scale of observation, what flows and how this flow happens, what causes permanence and change, what do metabolic rates actually measure and what is to be regulated.

Reading across all interviews, we have identified three distinct perspectives in approaches to urban metabolism which are not necessarily directly related with one disciplinary field. Instead, it appears that these distinct interpretations of urban metabolism emerge at the confluence of disciplines. From our analysis of urban metabolism, read in the context of the broader literature review that has been conducted for this project, we have identified three perspectives:

- the **Functional Analogy** emphasises urban metabolism as conducting the functions that reproduce the city;
- the **Form Analogy** uses the concept as a entry point into the internal configuration of the city;
- the **Dialectical Production** emphasises urban metabolism as directing the production of urban economies and their distribution.

We situate these perspectives at the confluence of civil engineering, economics, planning and geography.

The -Functional Analogy: a Physiological Perspective on the City

Urban metabolism implies reflecting on the city and its operation as a living organism. However, there are significant differences in looking at a living organism morphologically- in terms of its anatomy- or physiologically – in terms of its function. The approach on urban metabolism emerging in industrial ecology and bio-economics assimilates the city as a cell or a single organism that relies in specific outputs and produces wastes. The analogy is deployed in a functional way. Essentially, if we consider the city as producing an overall amount of energy or work, this approach focuses on how a specific metabolic rate of production is maintained. Even in broader conceptions of the city as an ecosystem the focus is on the functions that the city meets as a whole and how they can be maintained.

Applying such analogy has an immediate impact on the scale of analysis. Talking of urban metabolism, as opposed to social metabolism, implies that the scale of observation is brought from the international to the local level. Robert Biel (Bartlett, DPU)¹ highlights the need to understand the role of the urban in broader systems. This enables shifting the focus of analysis to the flows through the city- inputs and outputs- and how these maintain urban

¹ Dr Robert Biel, Senior Lecturer, Development and Planning Unit. Interview conducted on 21/07/2011, London.

functions. In order to do this the city needs to be conceptualised as a single entity, through which simple metabolic models are observed from a macroscopic perspective, a limited and limiting approach in the view of several interviewees.

Functional urban metabolism models measure flows in relation to the black box organism- the city- in terms of inputs and outputs. Inne Steenmans (Bartlett, Planning)² explains that “urban metabolism is about energy and nutritional flows in the city both in terms of their intake, their processing, and their output”. By focusing on inputs and outputs the models can describe different resource transformation rates, whether this is in terms of readily used resources (e.g. concrete, wood, minerals) or even chemical and energy flows. Overall, the outcome is an alternative to conventional models of urban management based on cost-benefit analysis, in which, as explained by Paul Ekins (Energy Institute)³, the city’s functions are measured only in terms of imports and exports and the whole system of flows reduced to chrematistic measures. Urban metabolism models, instead, provide a theoretical ground for the re-materialisation of urban economic theory, bringing in the ecological basis of the city economy. As observed by Kristy Revell (CEGE)⁴, these models- as applied to Hong Kong and Taipei- can provide a basis to measure the use of resources through time and thus, she argues, urban metabolism becomes “a useful concept to measure the city’s longevity, as per the carbon footprint performance indicator”.

This perspective describes flows in term of inputs and outputs. In conventional economic analysis, flows are considered to be for the most part linear; this means that for a given input on one side of the black box, there would be an output [waste] resulting from the metabolisation of such resource. However, there are opportunities to close such flows into a circular loop, in a manner in which the outputs can be reintroduced as new valuable inputs back into the city. The key concept here is looking at the city through circular, rather than linear models, as Joanna Williams (Bartlett, Planning)⁵ explains, such an approach enables the possibility of reframing urban environmental planning not simply as the efficient management of linear inputs and outputs but as an strategy for ‘closing the loop’, for instance through the recovery of valuable nutrients often disposed as liquid waste into local food production systems. Perhaps the most influential of these accounts is the introduction of the concept of “carbon cycle” in understanding cities’ contributions to climate change.

The normative implication of closing the loops as a recipe for sustainability has its grounds on ecology, rather than on cell biology- as living organisms also produce waste. Thus, ecology provides new concepts that enable thinking through how such circular approach can actually happen. Industrial symbiosis, for example, follows the hypothesis that there are optimum ways to organise industries so that some industries can use other industry’s waste as a resource. Urban infrastructures are conceptualised as the conductors of these flows, and thus, they have a protagonist role in creating and maintaining circular loops. Here, the approach looks into the potential for developing either technologies or planning systems to integrate different resource flow streams. For example, Alessandro Lizzul (CEGE)⁶ doctoral

² PhD Inne Steenmans Postgraduate Research Student, Urban Sustainability & Resilience, Interview conducted on 29/07/2011, London.

³ Prof Paul Ekins, Professor of Energy and Environment Policy, Energy Institute, Interview conducted on 29/07/2011, London.

⁴ PhD Kristy Revell, Postgraduate Research Student, Urban Sustainability & Resilience, Interview conducted on 28/07/2011, London.

⁵ Dr Joanna Williams, Senior Lecturer, The Bartlett School of Planning, Interview conducted on 19/07/2011, London.

⁶ PhD Alessandro Lizzul, Postgraduate Research Student, Urban Sustainability & Resilience, Interview conducted on 28/07/2011, London.

research explores how to integrate industrial flows in close loops in the urban system through the incorporation of algal photo bioreactors in built environments. This technology based on algae growth is intended to bring together different flows, such as CO₂, heat, nutrients and particle matters from wastewater. In her PhD, Inne Steenmans focuses on cross-sectoral planning to integrate different resource flows, following the planning model applied in Hammarby Sjostad, Sweden, as a strategic approach to urban planning. In terms of scale, these works focus on an integrated approach to urban flows at the city or urban-region level, rather than examining their separate components.

Metabolic rates are calculated in terms of the energy or work produced by resource unit, and the transformation of resources from inputs to outputs. Thus, changes in metabolic rates are related to the development of infrastructure networks in closed loops associated to the consumption society, although they could conceivably be also applied to the investment of time or any other variable through labour and economic flows. Not surprisingly, production of outputs as waste is interpreted as compromising the long-term sustainability of the system. As a result, waste management and waste reutilization are the main pillars in this approach. Resilience is thus enabled through the transformation of linear into circular flows. The idea of metabolism is directed at regulating the direction of flows to maintain urban functionalities.

Paul Ekins (UCL Energy Institute)⁷ highlights that, despite the reservations about whether the city can be understood as a biological organism, the analysis of material and energy flows in urban metabolism studies has contributed to reveal the physical basis of the economy. This not only contests traditional approaches to evaluate the city's performance but also, contributes to debunk recent theories of sustainability such as the hypothesis of dematerialisation. Many see potential in these concepts to develop integrated close loops in urban planning. Notwithstanding, the functional perspective in urban metabolism overlooks the interactions in the city and how they shape the transmission of flows, and as Joanna Williams puts it, how the local context limits technical applications- from lifestyles to the development of the built environment. Ultimately, looking at resource and energy flows may move away from monetary understandings of resources, but may fail to incorporate the social and cultural aspects of urban life.

The Form Analogy: a Morphological Perspective on the City

The morphological view on urban metabolism emerges in dialogue with the physiological view, in terms of conceptualising the city as a system of social and ecological components. The main feature of this perspective is a shift of attention from circulation to interconnection. Although urban metabolism still enables the analogy of the city as a living organism, here the emphasis is on the anatomy of the organism, its internal organisation. This extends the focus on resources to an increased attention of social processes. As Nick Tyle (CEGE)⁸ remarks "The city is not only a collection of buildings, it is a collection of people. Civil engineering should be a social science, and should aim to construct cities to live in. Just as an organism, cities do die." This quote highlights the integration of a simultaneous understanding of urban metabolism as a social and biological process. Similarly Mike Batty

⁷ Prof Paul Ekins, Professor of Energy and Environment Policy, Energy Institute, Interview conducted on 29/07/2011, London.

⁸ Prof Nick Tyler, Head of Department and Chadwick Professor of Civil Engineering, Civil, Environmental & Geomatic Engineering, Interview conducted on 11/07/2011, London.

(Bartlett, CASA)⁹ describes cities as “self-organising systems that grow organically from the bottom up. They are composed of entities – people and buildings – that have limited life spans and have to be renewed continuously.”

The immediate consequence of this perspective is a change of scale, which opens the black-box of the city and looks into its internal dynamics and configurations. Several proponents, specially Nick Tyler (CEGE), argue that the key question in urban metabolism is what is “the DNA of the city” or, in other words, what are the internal structuring principles of the city. The assumption is that the internal structure of cities organises and pre-empts the processes of growth and decay in different urban areas, in the same way as DNA is thought to prefigure certain traits and diseases in the human body. The idea of dysfunctionality- areas of the city which may hinder the normal development of metabolism- is relevant to understand the normative implications of morphological-analogy approaches. In terms of scale, the focus is not only in the organisation of the city per se, but also in how such configuration is determined by processes occurring at other scales, especially in the context of globalisation.

Returning to the original concern with movement embedded in urban metabolism, the question is “what flows” in a morphological understanding of the city? From this perspective, the answer to this question is often approached by exploring what elements of the city are able to develop connectivity and linkages. For Michael Batty (CASA), the lifeblood of the city is money and information, particularly considering how cities are related through global-local networks. For Revell (CEGE) “it is much more than resource flows... it is the people who make the metabolism.” For Alan Latham (Geography)¹⁰ - who has a long-standing interest on the processes of globalisation in the city- the central challenge to the notion of urban metabolism is “recognising that it is not just flows of materials, images and money, but also flows of people that define patterns of globalisation” and thus, shifting attention “to the personal and communal links that both transcend and weave together national boundaries.” Furthermore, Adriana Allen (Bartlett, DPU)¹¹ argues that a metabolism perspective need to encompass not just a wide set of flow (of people, capital, commodities, money information, natural resources and ‘waste’) but also could be productively expanded to apprehend whether such flows are leading to reciprocal or undermining linkages between cities and wider urban regions. In her view, this is important “to avoid approaching cities as islands of sustainability reform. An emphasis on the metabolism of rural-urban linkages is useful to assess not just if urbanisation trends are sustainable but more fundamentally whether or not they can potentially lead to reciprocal sustainable development both in cities and their adjacent areas.”

Because the attention moves towards the establishment and rupture of linkages, the urban metabolism terminology used in this perspective relates to the processes of building and breaking morphologies, specifically the interrelated ideas of anabolic and catabolic processes. Within a cell, anabolic processes are processes of synthesis where new structures are linked together by the incorporation of additional forms of energy. Catabolic processes are those in which structures are broken down to extract energy to maintain anabolic processes. Equally, the analyses developed from the perspective of the morphological

⁹ Prof Michael Batty, Professorial Research Associate and Emeritus Professor of Planning, Centre for Advanced Spatial Analysis, Interview conducted on 28/07/2011, London.

¹⁰ Dr Alan Latham, Senior Lecturer in Geography, Department of Geography, Interview conducted on 12/07/2011, London.

¹¹ Dr Adriana Allen, Senior Lecturer, Development and Planning Unit, Interview conducted on 15/11/2011, London.

analogy focus on the forces that lead to anabolic and catabolic processes in the city. For Alan Latham (Geography), for example, looking into the sorts of mobility that define the contemporary city requires examining “the role of friendship networks and personal relationships in configuring people’s movement.” This implies that infrastructure is important insofar as it sustains economies or populations, as the fabric of the city, but adopts a secondary role in the constitution of the city. More important, however, are the mechanisms of establishing and breaking up connections.

For Tom Cohen (CEGE)¹² the urban is a key arena to understand the emissions of GHGs. In the context of responding to climate change, metabolism may help to examine “the complex relationship between citizens and their governments and the spaces they inhabit, and the changes in one that lead to changes in other.” In his account, there are deliberate forms of agency able to reconfigure the relationships within the city: “considering the city as a fabric and the material flows between the governments and the fabric, the government chooses the form of the fabric to perform a certain activity and the citizen want to live in this fabric and change it. The metabolism entails also changes in players, in their interactions and in their own ways. The government may become trusty and the citizen more accepting of the government in the need to act. The fabric needs to change dramatically too, in order to adapt to climate change.” Thus, the interactions between government and citizens, in a simplified model, imply the building and rupture of linkages with shape the “form of the fabric of the city”, its morphology.

What, then, brings about permanence and change in “the fabric of the city” and the interactions performed on it? If the focus is on people, it follows that regeneration is a key process in terms of renewing and changing urban linkages. Professor Batty argues that “...medical and technological innovations are changing the length of these cycles quite dramatically. People are living longer and it is increasingly easy to either redevelop buildings quickly or to build them in materials that have greater durability. But to survive and to respond to new challenges, cities are continually regenerating and renewing themselves. Indeed, regeneration is the mark of any living system, and in cities, most activity that takes place can be considered as part of this process of renewal. New growth or absolute decay tends to be a relatively small proportion of the total change. Indeed, cities are continually in flux as people and their activities respond incessantly to changed circumstances, which involve shifts in movement patterns, locations, the use of buildings, and in social preferences...” Here urban metabolism is used to activate concepts of renewal, decay and change in the human body as applied to understanding urban regeneration. The emphasis is not on the processes that maintain the city but in how disruptions and disfunctions shape the morphology of the city. If we use the ecosystem analogy to understand the city, in the functional version the focus is on the processes of circulation which guarantee the continuity of the ecosystem, while in the morphological version, the focus is on the disruptions- fires, droughts, floods- which shape new distributions and enable new ecosystem structures. Because metabolic rates focus on morphological transformations, these approaches are concerned with questions of urban allometry, that is, the relationship between size and shape. It is the change of this rate which becomes worthy of examination- rather than the change of resource flow rates. Thus, there is often an interest in understanding metabolic rate changes comparing cities in different locations, with comparative analyses of urban networks and urban allometry. These metabolic rates may be heterogeneous within the city level: understanding the morphology of the city is thus akin to revealing the different metabolic rates, avoiding black-boxing the city as a whole.

¹² PhD Tom Cohen, Doctoral student, Civil, Environmental & Geomatic Engineering, Interviewed on 13/07/2011, London.

Kristy Revell PhD project of understanding informality is an example of the use of urban metabolism and demonstrates the commitment of this perspective with the aim of reconceptualising the city and its elements. She argues that “Cities need to be planned in a way that allows them to be flexible, nimble and adaptable so that they can adjust quickly in response to unknown difficulties of the future.” Urban metabolism is for her a model to measure the city’s flexibility: its resilience. In this context, informal settlements are thought of being more flexible and agile, and having a highly metabolic rate. According to Kristy Revell, there are things to learn from informal settlements, in particular, “their adaptability and efficiency, and the metabolism concept helps to look at their dynamics, giving their shortage in resources.” For Castán Broto¹³ and Allen (Bartlett, DPU) it is in the interface between urban resilience, informality and urbanisation as a process (rather than a focus on cities as ‘objects’) where the notion of urban metabolism has the potential to rejuvenate current practices and intellectual enquiries on urban sustainability and sustainable urbanisation. Castán Broto adopts a cautious approach emphasising that “the straight application of urban metabolism metaphors to informal settlements emphasises their regulatory function (economic, social and material) in the capitalist city, without challenging the economic drivers which lead to informality in the first place.”

The flexibility of connections and their capacity to respond to processes of decay and disruptions contribute to develop a deep understanding of the resilience city. Taking transport as a key component of urban mobility, Nick Tyler explains that: “In transport... cross-railing may not be such a good idea because it will feed the inner city beyond its capacity to handle the mass/energy, and make the problems of the centre worse. Just like to feed endlessly a person that is hungry will get him fat, the energy in the city needs to be spread out and needs its suburbs for this. There needs to be a balance, to maintain the metabolism, distribution of the vitamins in order to have a healthy body. The London tube is stuck with its heavy infrastructure; it’s very hard to change. Heathrow may be seen as a tumour, because of its spatial-temporal location (between the west-east hemisphere), and although its hard to see it as something organic because it is made of steel, concrete and metals, it is part of London organism and feeds the city with social/environmental problems and economic/political benefits.”

Overall, we see in this example a collage of the themes discussed above, specially the linkage of ideas of decay and disease with the morphological distribution and organisation of the city, and the connectivity and linkages between the different functions. This approach is pioneering new concepts and understanding forms about the city; yet, its proponents often find difficulties in relation to how to establish measurable indicators of the linkages, beyond measuring resource flows. Rather than measuring the flow rates, the focus here shifts to revealing the internal structure of the city, the underlying principles which organise it-whether it is personal relations; monetary exchanges; government interventions; or initial distribution of infrastructure and resources. In both perspectives, Physiological and Morphological, urban metabolism is used to bring about a metaphor from the biological sciences to the study of the city. For Alan Penn (Barlett, Graduate Studies)¹⁴, borrowing concepts from other disciplines reveals that “urban science is not well formed as a science in its own right.” He finds these scientific analogies suspicious because urban and social systems have different laws and processes: “Yes, cities have energy and resource flows, but do they

¹³ Dr. Vanesa Castán Broto, Lecturer, Development and Planning Unit. Interview conducted on 22/11/2011, London.

¹⁴ Prof Alan Penn, Dean of Faculty, Professor of Architectural and Urban Computing, Bartlett School of Graduate Studies, Interview conducted on 13/07/2011, London.

have a Krebs cycle? How useful is the analogy?” On the one hand, scholars inspired by the urban metabolism analogy have put a great effort in developing practical applications about the theory. Much of the work has been on design solutions- at the level of the individual development and its distribution around the city. Yet, the fundamental challenge posed by several interviewees is whether these theories (and the practical applications derived accordingly) built upon plausible representations of the city.

Dialectical Production: a Perspective on the Political Economy of the City

The third perspective on urban metabolism is very different because it is not built on an analogy of the city as an organism or ecosystem but rather, it is predicated on an understanding of metabolism as enabling the processes of production and consumption, which constitute modern economies. This understanding builds upon Marx classical work on social metabolism, describing the relations underpinning systems of production. Here, the concept encompasses both social relations and ecological relations. Urban metabolism emerges in opposition to rural metabolism to emphasise the differences in terms of speed and rates of accumulation in different systems, considering that classical Marxism conceptualised the city as the nucleus of the capitalist mode of production. Neo-Marxian readings of urban metabolism, however, highlight the centrality of ecology and nature as not only facilitating but, as highlighted by Robert Biel (Bartlett, DPU), also determining the form of the processes leading to capitalism reproduction. For Biel, a fundamental question concerns the extent to which urban metabolism perspectives can capture how nature is inserting itself within the built environment. The maintenance of metabolisms- fundamentally urban- is predicated in two central contradictions as described by James O'Connor. The first contradiction “expresses capital's social and political power over labour, and also capitalism's inherent tendency toward a... crisis of capital over-production”. The second contradiction focuses on capitalism’s “economically self-destructive appropriation and use of ... urban infrastructure and space, and external nature or environment”. Thus, capitalism is predicated both on the exploitation of the labour class and the resource base. In this interpretation, urban metabolism highlights the effects of the second contradiction, that is, the exploitative relationship of capitalism and urban natures. Allen (Bartlett, DPU) finds here the potential to interrogate the socio-environmental inequality of different urban metabolisms, arguing that only by re-embedding such analysis into a wider political ecology perspective it is possible to establish whether or not apparently efficient and sustainable outcomes are being achieved at the expense of specific groups and territories. Her contention is that “under the latest phase of the treadmill of production, the emerging geography of capitalist accumulation is increasingly being shaped under conditions of ‘differential sustainability’, that is by adjusting thresholds to meet the needs and wants of certain privileged social groups and territories at the expense of others.” In this sense, dialectical takes on urban metabolism are critical of the use of this concept to describe what flows permeate the city and are instead concerned by exploring who gets affected and who benefits from different metabolism and why. Scale is a central concern within political economy interpretations of urban metabolism, but not in terms of having a determined, fixed scale but in terms of approaching scale as socially constructed. Castán Broto (Barlett, DPU) argues that the rates of metabolism characteristic of concentration and accumulation in urban centres “will be determined by both broader structural processes- such as capital globalisation- and micro events- such as individual practices”

Nick Beech's (Bartlett, Planning)¹⁵ highlights the vocation of the political economy perspective to understand the interrelationship of urban metabolism at different scales, emphasising in particular what positions of authority and power are able to establish and determine the spatial and temporal location of specific forms of transformation. He is specifically interested in "how to engage the ordinary and the production of space and thus, how architecture is reproduced through its occupation. Thus, he studied "architecture as a product in the contest over knowledge". He concludes that "practices are not just pragmatic responses to a situation but they are laid in the culture: attached to them you find a whole set of systems of knowledge and the production of knowledge". Seemingly random practices, such the specification of contracts in the history of architecture, can have an important impact in determining one or a series of metabolic transfers. Thus, Nicks identifies a system of "crystallised practices" that respond to broader cultural contexts within which the capitalist economy is reproduced.

The question here is if human beings and natures are enmeshed in a simultaneous process of transformation under capitalism, what are the objects that facilitate this transformation? In other words, what is it flowing? In the example above, the transfer of knowledge, authority and power in the form of the specification of a contract emphasises that what flows are systems of legitimisation and knowledge, which enable the circulation of capital, labour and resources. According to Matthew Gandy (Geography)¹⁶ the appeal of urban metabolism is the simultaneous appreciation of the close relationships between infrastructure, water, public health, bio-politics of the human body and the different understandings of nature in the city. Infrastructure becomes not only a conductor of resources, the city's fabric but rather the tools for the transformation of nature and its integration into the economic system. Simultaneously, infrastructures embody the inequalities which reproduce the first contradiction of capitalism, highlighting the unity of crisis- socioeconomic crisis and ecological crisis- as foundational principles of capitalism. The urban system is perceived by Robert Biel (Bartlett, DPU) as "a heavily alienated system" because "urban metabolism as a capitalist political economy is fundamentally contradictory to nature and to the long term survival of humanity and that is what dominates the urban system." The question raised here is whether the urban is the fundamental organization form of capitalism, or whether alternative forms of urban metabolism exist beyond the capitalist system which do not necessarily reproduce its second contradiction.

The urban metabolism concept is adopted here cautiously, looking at, in particular, "what particular work does this metaphor perform in the political arena" (Matthew Gandy). The focus is both on the circulation and the linkages that enable the reproduction of power and knowledge and looking into how those particular discourses facilitate or hinder particular transformations becomes the key activity towards a more sustainable society.

What this perspective offers, above all, is a note of caution on the uncritical application of biological metaphors to interpretations of urban change. Gandy highlights that looking for the city's DNA, for example shifts attention from Marx (and the forms of authority that enable the reproduction of a particular system of production) to Darwin (the self-regulating capacity of populations to adapt to change). Both Gandy and Biel highlight the dangers of urban metabolism inspired concepts of urban resilience. Biel argues that the capitalist political economy is very resilient, as it is grounded on its potential to respond to crisis, and

¹⁵ Dr Nich Beech, UCL Teaching Fellow* , The Bartlett School of Architecture, Interviewed on 12/07/2011, London.

¹⁶ Prof Matthew Gandy, Professor of Human Geography, Department of Geography. Interviewed on 28/07/2011, London.

yet, simultaneously is intrinsically unsustainable and leading humanity to an impending disaster. In contrast with these two views, Allen sees approaches the notion of urban resilience not just a structural predetermined outcome – a mere crystallisation of global economic forces but as a way to investigate the agency of space and of place-making and their oppressing and liberating potential. For instance, in association with other colleagues she has looked at the built-in resilience of the urban poor to deal with climate variability in contexts like Dhaka, unveiling how collectively matured responses offer key entry points to reframe planning responses to climate change adaptation in cities. Where all scholars whose work is aligned with this perspective agree is in that a dialectical perspective on urban metabolism warns against technocratic forms of urban management building on the legacy of engineering rather than on dialogue with social sciences.

Way forward

As stated in the introduction, this paper should be regarded as an open path aimed to trigger further interdisciplinary debate and collaboration within UCL while engaging scholars with wider conceptualisations and applications of the notion of urban metabolism. Our departing and concluding point in the process generated by this project is that the potential of this concept lies in the interdisciplinary dialogues that it fosters across radically different disciplines. This dialogue can bridge urban debates across sustainable engineering, critical geography, ecological economics and development planning. The perspectives outlined in this document indicate not only that urban metabolism operates at the boundaries between different disciplines, but that its potential to shed further light on how to approach urban sustainability as a distinct area of intellectual enquiry and practice lies precisely on the productive dialogue between interdisciplinary convergences and divergences.

The previous discussion resonates with the wider urban metabolism literature, especially in relation to the potential contribution that a focus on circulation and movement in the city brings to debates on urban sustainability; the re-conceptualisation of urban infrastructures-notwithstanding the different interpretations of what is urban infrastructure- and the assimilation of long-term sustainability objectives with resilience. Furthermore, the three perspectives outlined above reveal certain malleability of the concept, and multiple assumptions about what different things mean. Table 1 summarises some of the key tenets and assumptions ingrained within each perspective

Acknowledging a high degree of heterogeneity across the three aforementioned perspectives, overall urban metabolism appears to be a powerful cross-cutting concept, enabling fruitful dialogue and innovation across disciplines. Its impact can be assessed in particular in relation to three significant contributions. The first concerns the development of ecological economy concepts to reveal the material basis of the urban economy. The second refers to the articulation of social dimensions in civil engineering and the development of socio-technical understandings of urban infrastructure. The third substantial impact lies on the urbanisation of political ecology, bringing in the political dimensions of the concept. Latent in the previous discussion is the potential to pursue a **political ecologisation of urban studies and practice**. We view this as route to critically explore the full scope of biological metaphors, while avoiding the danger of depolitisation by simply collapsing social/cultural/affective components of urban spaces in such biological metaphors.

It is evident that given the complexity of urban and social processes there are many aspects of the environment and its planning in which it may be best to conceptualise systems in

ecological or organic terms – that is where no single central process of planning and control can be used to account for behaviour and system dynamics, but where processes are contingent and emergent. In these situations the concept of ‘urban metabolism’ becomes a useful path to interrogate the city, its flows, functions, DNA and bio-physical and socio-political regulation mechanisms. We hope this paper will contribute to fuelling further debate and collaborative action.

Table 1: Key differences between alternative interdisciplinary perspectives in Urban Metabolism			
	Functional Analogy	Form Analogy	Dialectical Production
Conceptualisation of the city	City as a single organism, either a cell or an ecosystem	City as a living organism but moving from a collection of buildings to a collection of people	City as a cyborg of social, technological, ecological relations supporting capitalism reproduction
Scale of observations	City, black-boxed as a whole entity	Understanding the underlying structures organising urban life, its DNA	Scale as socially constructed- multi-scalar perspectives
What flows	Resources and Energy, from inputs to outputs	Populations and economies, although in close interdependency with resources	Authority, legitimacy, knowledge-building objects
How does flow happen	Unsustainable flows are linear, unidirectional, and sustainable ones circular	Catabolic and anabolic reactions establishing and breaking linkages and connections	Mechanism of control and hegemony in crystallised practices in opposition to activism and contestation
Conceptualisation of Infrastructure	Conductor of resources and energy	Constituting part of the fabric of the city	Facilitates the transformation of nature into the economy
Causes of permanence and change	Top-down technological or planning reinterpretation of flow conductors	Bottom-up constitution with morphological disfunctions and design failures	Crisis are intrinsic to the reproduction of capitalism
What do metabolic rates measure?	Transformation of resources from inputs to outputs	Capacity to re-establish constitutive urban linkages	Potential to reformulate the exploitative relationship between capital and nature
What is to be regulated through metabolism	Rates of resource and energy use (and waste production)	Both the maintenance of linkages and morphological disfunctions	Under capitalism, the processes of capital reproduction
Concept of resilience	Resource maintenance in a limited, bounded world	Flexibility to redefine the constitution of the city	Associated with the potential for social creativity within the economy
Key practical implications	Planning and technological solutions for resource flow integration	Redefining the city conceptually and focus on design-led solutions	Need to question discourses of power and authority
Examples	Hammarby Sjostad, Sweden	Transport-land models Recognition of the regulatory functions of informal settlements	Historical studies of changes in the history of architecture