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Prithwish Mukherjee [*,†]

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Article

The Biological Identity Crisis: Persistence Without Material Continuity

Prithwish Mukherjee †

Harvard University, 1875 Cambridge Street, Cambridge, MA 02138, United States;
mukherjeeprithwish1999@gmail.com

† Current address: Flat I 208, Fortune Heights, 168 Krishnanagar Road, Kolkata, India.

Abstract

Living organisms are materially dynamic systems. Proteins are continuously synthesized and degraded, membranes are remodeled, metabolites are exchanged, organelles are renewed, cells can be replaced, and tissues can undergo substantial structural change. In spite of all these, a living organism may remain the same biological individual throughout these transformations. This gives rise to a question: If persistence of matter is not required for persistence of the organism, what exactly is preserved through biological changes? Autopoietic theory, organizational approaches to biology, and works on diachronic identity have all emphasized processes of self-maintenance, organizational closure and continuity through change. This paper does not claim to discover the general idea that biological identity is organizational rather than merely material. Rather, it identifies the following gap: biological discussions often move between material continuity, and numerical identity without separating these distinct notions clearly. The paper argues that this distinction deserves explicit treatment in mainstream biological reasoning. "Material turnover" is a measurable empirical phenomenon, whereas "Organismal persistence" is a continuity judgment made across time. These two are not equivalent variables. An ideal framework should therefore distinguish the changing physical substrate from the persistence of the organization that coordinates this substrate, also recognizing the role of historical continuity. The central proposal of this paper is that studies of biological persistence should state explicitly whether they are tracking material, structural, functional, organizational or historical continuity. I end the paper with a research agenda for testing whether measures of organizational continuity provide a better description of organismal persistence than measures based on material similarity alone.

Keywords: biological identity; organizational persistence; material turnover; individuality

1. Introduction

A living organism is treated ordinarily as a persisting individual. The infant and the adult are considered to be the same organism. The cell before division and the cell after extensive remodeling is considered as a continuing lineage. An animal remains the same individual while its tissues continually repair and remodel themselves. This seemingly ordinary statement has a theoretical problem. Biological systems persist precisely by changing

The problem becomes visible when identity is considered against the dynamics of biological matter. Living tissues are in a continuous state of synthesis, degradation, recycling, transport, and remodeling. Stable-isotope methods can quantify protein synthesis and breakdown, and modern tracer approaches have established that tissue protein pools are continuously renewed rather than being permanent (Trommelen and van Loon, 2024; Deutz and Engelen, 2024). Protein turnover is not only an exceptional response to injury. It is a part of ordinary tissue maintenance. Proteostasis itself is an active network involving synthesis, folding, transportation, degradation and quality control (Köhler & Andréasson, 2023)

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The persistence of an organism hence does not simply mean persistence of the same molecular inventory. Neither is persistence reducible to preservation of a fixed anatomical shape. Development, remodeling, regeneration, and physiological adaptation can substantially alter structure preserving organismal continuity

This ultimately leads to the central question presented in this paper: "What in biological terms makes an organism the same organism through passing time when the matter from which it is constituted is changing continuously ?"

2. The Paradox of Biological Persistence

Organisms are physically constituted by matter, but organismal identity does not appear to require the persistence of the same matter. At first glance, this can resemble the classical philosophical problem of the Ship of Theseus. However, the biological case is more demanding since living systems don't merely tolerate replacement of parts. They actively produce, replace, regulate and repair their components through coupled processes

Consequently, the relevant contrast is not simply between an unchanged object and a changing object. It is between two modes of persistence- persistence of constituents and persistence of the organized system that uses, replaces and coordinates these constituents

This distinction is important since biological research commonly operates at multiple levels simultaneously. A proteomics study may track changes in molecular abundance, a microscopy study may track cellular architecture, a physiological study may track function, while a lineage study may track ancestry. Each can describe change or continuity, but none automatically answers the same question on identity

3. Material Continuity Is Not Organismal Continuity

Material continuity is the persistence of physical constituents. At any chosen scale, it can be measured by tracking molecular, cellular, or tissue components across time. It is an empirical property of matter

Organismal continuity is different. It concerns whether a later biological state is understood as the continuing state of the same individual rather than as a newly constituted individual. The distinction becomes obvious in developmental biology. The organism at one developmental state may differ greatly in size, anatomy, cellular composition, physiology and molecular state from the organism at a different stage. Nevertheless, biology treats the developmental sequence as the history of one organism rather than the serial appearance of unrelated organisms

The same logic applies to repair and remodeling. If an organism loses a component and regenerates it, material composition has changed. What makes the regenerated structure part of the same organism is not the preservation of identical material particles, but the continuity of the processes through which the organism maintains and reconstructs itself

This does not imply that matter is irrelevant. Organization is always physically realized. But the criterion of identity cannot be same as the criterion of material persistence

4. Organization as an Existing Solution

The theoretical biology literature has already developed major approaches to this problem. Autopoietic theory characterized living systems in terms of a network of processes that produce and maintain the components required for their continued organization (Maturana and Varela, 1980). This framework shifted the attention from the persistence of parts to the self-producing dynamics of the system

A more formal approach was developed by Montévil and Mossio (2015), who characterized biological organization as closure of constraints. Their framework distinguishes changing processes from constraints that remain relatively conserved over relevant timescale and argues that biological constraints are mutually dependent in maintaining the organization of the system

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This literature is directly relevant since it provides an account of how biological stability can co-exist with material change. Organization is not a frozen arrangement of components. It is maintained through processes in which constraints and activities contribute to one another

Importantly, the problem of organismal identity has also been addressed explicitly. Montévil and Mossio (2020) examined historical and relational conceptions of organismal identity and discussed organizational continuity as a way of understanding persistence through functional and developmental changes. DiFrisco and Mossio (2020) similarly argued that diachronic identity requires a continuous causal process linking successive organizational regimes, while also noting that organizational continuity alone does not settle all questions regarding individuality, specially in reproduction, fission and fusion

5. The Remaining Conceptual Gap

If organizational continuity is recognized already, what exactly remains to be addressed ?

The term “continuity” may conceal several different claims. A system may exhibit continuity of material constituents, continuity of structure, continuity of organization, continuity of function or continuity of lineage. These forms of continuity can move together, but they do not need to

Development is a clear example- functional capacities can change while historical continuity persists, material components turn over while organizational relationships remain sufficiently stable, and structure can change while the organism remains the same individual

Without explicit separation of these concepts, statements like “the organism remains the same because its organization persists” sound circular. What aspect of organization persists and at what scale ?

If organization is defined so broadly that every successor state is automatically organizationally continuous, the explanation becomes unfalsifiable. If it is defined too narrowly, then even ordinary development and repair appear to destroy identity

The central issue is therefore, not whether organization matters. Existing literature already provides strong reasons that it does. The unresolvable issue is how biological research should distinguish between the different kinds of continuity, and determine which are relevant to a particular claim about identity

6. A More Precise Biological Vocabulary

I propose that discussions of organismal persistence should explicitly separate at least the following five notions of continuity-

1. Material continuity concerns persistence of constituents
2. Structural continuity concerns persistence of spatial or architectural relationships
3. Organizational continuity concerns persistence of causal relations and constraints through which the system maintains and transforms itself
4. Functional continuity concerns persistence of roles
5. Historical continuity concerns connection through a continuous lineage or causal history

These categories are not competing definitions of the same thing. They are different dimensions of persistence. An organism can show low material continuity retaining high organizational and historical continuity. Two independently generated systems can show high functional or organizational similarity lacking shared individual history. A regenerating organism can restore function after major structural disruption without requiring material identity with the pre-injury state

These differentiations do not solve the identity problem by itself. It prevents different kinds of continuity from being treated as interchangeable

7. Why This Distinction Matters for Biology

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This distinction is relevant and important because many biological explanations depend on assumptions about identity through time

Like in longitudinal studies, researchers often compare measurements from an organism at different time points and interpret differences as change within the same biological individual. That inference is generally justified by experimental continuity and lineage, not by molecular sameness. Recognizing this makes the basis of the inference explicit

In developmental biology, the distinction clarifies why large transformations don't constitute repeated replacement of the organism. In regeneration, it separates reconstruction of a tissue from the creation of a new individual. In cellular differentiation, it separates changes of state from questions of lineage and individuality. In physiological transformations, it can be useful to differentiate between continuity of the physical substrate and reorganization of the regulatory system

The distinction also matters for structural biology. Contemporary approaches increasingly emphasize networks, feedback, regulation and multiscale interactions. Yet, a network representation is still a representation at a selected level. Treating an inferred network as identical to the organism itself gives rise to risks of conflating a model of organization with the historical biological entity being modeled

8. The Organism as a Continuous Process

The biological identity problem may be better expressed as a problem of process persistence rather than object persistence. It is a system whose ongoing activities help maintain the conditions under which those activities can continue

This process based view does not deny physical continuity. Rather, it changes what is considered fundamental for identity. Material constituents are continuously recruited into, modified within, and released from the organism. The persistent entity is consequently not a fixed material inventory but a temporally extended process that continually reconstructs its own physical basis

This perspective is closely related to established organizational theories and should not be treated as a replacement for those. Its purpose is to highlight the conceptual consequence- if biological identity is processual, then a snapshot description cannot be the whole criterion of identity. Identity is a statement about continuity across successive states

9. A Testable Research Question

The central empirical question that follows is the following: "When organisms undergo change, does persistence of organism-level organization provide a more information description of continuity than persistence of material composition alone ?"

This question can be approached experimentally without committing to a new mathematical definition. Longitudinal studies can independently measure molecular turnover, physiological function, structural remodeling, lineage continuity and regulatory interactions. The objective will be to determine which dimensions of change remain coupled to the continued persistence of the organism as an individual

Stable-isotrope tracing is particularly relevant since it already provides quantitative information about turnover of proteins and other metabolites across biological timescales (Trommelen and van Loon, 2024). Modern multi-omics and systems approaches can then be used to examine whether large scale molecular replacement occurs alongside preservation of higher level organizational relationships

A strong experimental design will deliberately compare systems with different degrees of material turnover but similar organismal continuity, and systems with similar material composition but altered organization. Such comparisons will make it possible to test whether material similarity and organizational continuity carry distinct explanatory information

10. Boundaries and Counterexamples

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Any theory of biological identity confront cases in which continuity is ambiguous. Reproduction raises the question of when a new individual begins. Fission can generate multiple descendants from one organized system. Fusion can combine previously separate systems. Horizontal exchange can transfer biological components across lineages. Microbial communities challenge the boundary between an individual organism and a higher level collective

These cases are not reasons to reject the organizational perspective. They demonstrate why identity cannot be inferred from organization alone. Historical continuity, causal continuity and changes in the number of organized systems may all be relevant depending on the biological question. The literature on organismal identity has already emphasized these complications, particularly for fission, fusion and reproduction (DiFrisco and Mossio, 2020; Montévil & Mossio, 2020)

This paper therefore avoids proposing a universal identity criterion. Rather, it argues for explicit identification of the continuity relation being used in each scientific context

11. Towards an Empirical Science of Biological Identity

If organismal identity is to become an empirically tractable concept, future studies should move from the question "Are these two states the same ?" towards the more precise question "What continuity relation connects these two states ?"

This shift will permit experimental programs that separately interrogate material, structural, functional organizational and historical continuity. It also creates a route towards later formalization. A future theoretical paper can attempt to define an operational measure of organizational identity continuity using longitudinal causal or network data. Such a measure can then be compared against simpler measures of molecular or functional similarity

This paper intentionally does introduce such a metric. The conceptual distinction should precede mathematical formalization. Otherwise, equations risk giving a false impression of precision before the biological quantity being measured has been sufficiently specified

12. Conclusion

The biological identity crisis can be simple to state but difficult to resolve: an organism changes continuously while remaining the same organism. The empirical fact of material turnover is well established, and theoretical biology has long recognized that organization, self-maintenance and causal continuity are central to living systems. The conceptual problem hence is not the absence of an organizational perspective

The deeper issue is that several kinds of continuity are often compressed into the single word "identity". Material persistence, structural persistence, functional persistence, organizational persistence and historical persistence are related but not equivalent. Treating them as interchangeable obscures the basis on which biology recognizes a continuing individual

The central proposal of this paper is methodological- biological studies of persistence should explicitly distinguish between the type of continuity being invoked. Organismal identity should not be equated with persistence of matter, and organizational continuity should not be invoked as an undefined substitute for identity. Instead, the field should ask which aspects of organization remain causally continuous through material transformations and how those aspects can be observed and tested

The organism may ultimately be best understood not as a fixed material object but as a continuing biological process whose physical realization is continuously rebuilt. Making that proposition experimentally precise is a tractable next step for theoretical and systems biology

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