

## What comparative biology reveals about the explanatory role of representations

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The status of representations remains a central and contested issue in philosophy of biology and cognitive science. In recent decades, enactive, dynamical, and organism-centered approaches have convincingly demonstrated that many forms of adaptive, flexible, and apparently goal-directed behavior can be explained without invoking internal representations. By emphasizing real-time organism-environment coupling, distributed physiological dynamics, and the self-organizing properties of living systems, these approaches have significantly reshaped our understanding of biological cognition and challenged representationalism as the default explanatory framework.

However, an open question remains whether this non-representational strategy can be generalized across the full range of biological systems, or whether there are principled limits to such explanations grounded in biological organization itself. This paper argues that representational explanations provide genuine explanatory understanding only at specific points where non-representational accounts reach their limits, and that these limits coincide with a biologically significant organizational transition associated with the emergence of neurons.

The argument is developed within the framework of the representation-hungry problem introduced by Clark and Toribio (1994). According to this view, representations should not be treated as default explanatory posits but are warranted only when behavior cannot be adequately explained in terms of continuous dynamical coupling between organism and environment. The central philosophical task, then, is not to decide whether representations exist in general, but to identify when and why representational explanations become explanatorily indispensable rather than merely convenient or metaphorical.

To address this question, the paper adopts a comparative, empirically informed approach drawing on two biological case studies that differ in organizational complexity. The first concerns complex nutritional decision-making in the slime mould *Physarum polycephalum*, a non-neural organism. Experimental work shows that *Physarum* can flexibly regulate its intake from multiple food sources with different nutritional compositions, dynamically adjusting consumption in accordance with its internal nutritional state (Dussutour et al., 2010). This behavior involves the integration of multiple environmental variables, context-dependent

choice, and apparent optimization over time, and is frequently described using cognitive vocabulary such as “decision-making”, “preferences”, and “nutritional targets”.

Despite its sophistication, I argue that nutritional regulation in *Physarum* can be fully explained in non-representational terms. The relevant explanatory resources include distributed physiological processes, growth dynamics of the plasmodial network, and differential absorption rates, and continuous feedback loops between organism and environment. Crucially, the behavior does not depend on learned associations, localized memory structures, or the selective modification of internal states based on past outcomes. No internal states need to be interpreted as encoding relations between nutrients or representing nutritional goals. In this case, representational posits do not increase explanatory power or understanding, even though the behavior might *prima facie* appear to motivate them.

The second case concerns associative learning in the box jellyfish *Tripedalia cystophora*, an organism with a decentralized nervous system. Recent experimental work demonstrates that box jellyfish can learn to associate specific visual patterns with mechanical collisions and subsequently modify their swimming behavior to avoid obstacles (Bielecki et al., 2023). This learning is mediated by localized neural plasticity within the rhopalia and exhibits key features such as stimulus specificity, sensitivity to temporal relations, and persistence across changes in environmental conditions.

I argue that these features cannot be adequately explained by appeal to global biochemical changes or undifferentiated organism-environment coupling alone. Instead, they require positing internal states whose functional role is to selectively stabilize relations across time and guide behavior in contexts that are not currently present. In this case, representational explanations are not optional re-descriptions but are required to account for how learning is organized, maintained, and generalized beyond immediate interaction.

The contrast between these two cases reveals a qualitative evolutionary transition in biological organization. Neurons introduce new organizational capacities, including structurally localized plasticity, outcome-dependent modification of internal states, and the ability to stabilize behaviorally relevant relations across time. Together, these capacities undermine purely non-representational explanations and generate genuine representation-hunger.

The paper’s main contribution is to clarify how and when representations provide understanding in biological explanation. Representations do not merely label behavioral regularities; they explain why certain patterns of behavior are stable, selective, and counterfactually robust across time and circumstances. By grounding representational necessity in comparative biology and organismal

organization, this account offers principled criteria for determining when non-representational explanations suffice and when representational posits are explanatorily required.

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