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Qeios

Peer Review

# Review of: "Integrating Biological Principles into Observational Entropy"

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**Summary of the Work**

The study aims to expand the concept of observational entropy by integrating biological principles of information processing and knowledge acquisition. Since entropy is inherently tied to uncertainty from an observer's perspective, the authors argue that biological mechanisms, such as differentiation of signals, adaptation, and knowledge formation, must be included in entropy measures. This approach seeks to link physical entropy with the observer's epistemic framework, thereby refining its meaning in terms of energy usefulness, order, and predictability.

**Main Results Obtained**

i) Entropy is reframed as observer-dependent, shaped by the biological ability to acquire and interpret knowledge. Living systems transform raw information into knowledge, which guides adaptation and survival.

ii) Adaptation processes, described by replicator dynamics, integrate new information into the observer's epistemic framework, forming the basis of evolution and natural selection.

iii) Kullback-Leibler divergence is identified as a key metric for representing relative information between observer and observed. Integrating Darwinian principles with information theory may bridge gaps in understanding the physical world from an observer-centered perspective.

iv) Sensory mechanisms and organismal complexity (e.g., migratory birds' magnetic sensing) demonstrate how entropy and energy qualifications depend on biological capacities.

**General Comments**

- The English should be carefully reviewed, as several typos were found. Some sentences could be shortened.

- This study offers an original perspective by linking entropy with biological principles.

- The integration of information theory and biology is innovative and thought-provoking.

- However, this work could benefit from clearer definitions of key terms.

- Some arguments are repeated and could be more concise.

- The lack of empirical validation limits the strength of the conclusions.

- The observer-centered framework may reduce the universality of entropy.

The following suggestions are offered to help the author strengthen the paper by addressing some important gaps.

**Suggestions**

**1)** Does integrating biological principles make entropy a more comprehensive concept?

**2)** Could this approach help bridge physics and biology in understanding information?

**3)** How can the proposed model be tested or validated empirically?

**4)** Does the integration of biology risk making entropy definitions less precise?

**5)** How does this framework differ in practice from Shannon's model?

**6)** Could observer-dependence limit the universality of entropy as a physical concept?

*More technical questions*

**7)** In extending observational entropy with replicator dynamics, how is the standard entropy functional

$S$_{obs} (P‖C)=−∑_i P(i)ln P(i)/C(i)

(where P(i) is the observer's epistemic probability distribution and C a coarse-graining) formally modified? Specifically, does the replicator term introduce a nonlinear time-evolution of P(i,t) via a differential equation of the form

dP(i,t)/dt=P(i,t)[f(i,P)−{\bar f}(P)],

and if so, how does this affect the entropy production {\dot $S$}_{obs} relative to the Caticha–Cafaro entropic dynamics formalism?

**8)** When employing Kullback–Leibler divergence

D_{KL}(P‖Q)=∑_i P(i)ln P(i)/Q(i),


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to capture observer–system information exchange, which distributions are formally taken as P and Q? Is Q assumed to be the "objective" system distribution and P the observer's epistemic distribution, or is Q instead the prior distribution of the observer before updating? Furthermore, how does the choice between these alternatives alter the definition of entropy flux and entropy production in the extended observational entropy framework?

**Conclusions**

This manuscript presents an original and stimulating attempt to integrate biological principles into the framework of observational entropy. This interdisciplinary approach is innovative and may help bridge physics, information theory, and biology. However, several issues require clarification. Key terms such as information, knowledge, and uncertainty are sometimes used interchangeably, which risks blurring conceptual boundaries; a sharper distinction would strengthen the theoretical foundation. The text would also benefit from greater conciseness, as some arguments are repeated. More critically, the absence of empirical grounding or testable predictions limits the applicability of the proposed model. Furthermore, the emphasis on observer-dependence raises concerns about whether entropy retains its universality as a fundamental physical quantity. On the technical side, the integration of replicator dynamics into the entropy functional remains insufficiently developed: if the probability evolution follows a replicator-type equation, its impact on entropy production and consistency with the Caticha-Cafaro entropic dynamics formalism should be explicitly derived. Similarly, when applying Kullback-Leibler divergence, it is unclear whether the reference distribution represents the system's "true" state or the observer's prior; this ambiguity affects the interpretation of entropy production and its physical meaning. Addressing these points would considerably enhance the clarity, rigor, and impact of the work.

## Declarations

**Potential competing interests:** No potential competing interests to declare.