Title: Epistolution: A New Principle of Life

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Abstract: *Our predominant fundamental theories of biology assume that the organized appearance of life and the reliable recurrence of ontogeny are due to heritable influences. In this view, inheritance even carries responsibility for producing learning. Learning is thought to be confined to complex structures like brains, and it is assumed to be aimed at solving problems related to survival and reproduction. Perhaps this view is wrong on all three counts. Genetic selection could not have happened without phenotypes and all phenotypes may require learning to generate. The theory of life may only be complete if we posit a mechanism by which full-blown agency, involving beliefs, intentions, and desires, motivates every living cell rather than inherited programs. Both cells and organisms appear to use DNA for their own contingent, adaptive ends; I propose that biological inheritance may be impossible without this top-down control. I have named this form of learning "epistolution," combining "epistemology" and "evolution," to distinguish the idea from other concepts. Although all ontogeny requires epistolution, especially clear examples include embryonic development, wound healing, regeneration, cancer, memory, dreaming, creativity, swarm intelligence, epigenetic inheritance, and the placebo effect. I propose that the principles of epistolution, once known, may be generalizable and might be used to build artificial devices that create genuine subjective knowledge. This paper is an attempt to clarify epistolution to allow researchers to test models of it in laboratories, perhaps uncovering principles that can ultimately give us engineering ability over life, and cognition, for the first time.*

All adaptive plasticity as learning

Claims that all organisms have some form of "agency," that they make choices and pursue their own goals, are now commonplace in biological discourse [1, 2]. How could these claims be compatible with the assumption that ontogeny is organized by a comprehensive inherited program that aims at survival and reproduction? Goals cannot be both spontaneously self-created and also wholly inherited. If organisms were simply reading out a program of inherited solutions to problems encountered by their ancestors then genetically identical clones would diverge from one another randomly, not functionally. In contrast to mere teleonomy, agency seems to require a genuine purposefulness, involving beliefs, desires, and intentions.

Biological agency could be more coherently defined as the ability to form new, independent, individual goals through learning. This ability to learn is often viewed as an evolved and inherited trait programmed into the organism by its genes, but gene expression is controlled by the interaction between the phenotype and the environment [3, 4]. This makes genomic function a consequence of learning as well as a cause of it, so learning cannot be merely an evolved trait purely under genomic control [5]. What, then, makes learning "work?"

It requires at least some goal-seeking plasticity to get from any genotype to any phenotype. Adaptation to changing conditions is a basic feature of all embryonic development, even the development and reproduction of single cells [6]. For example, E. coli clones in slightly different environments adapt in modest ways metabolically, behaviorally, or morphologically to accommodate different conditions, and that adaptation has consequences for their gene expression patterns [7-10]. If we simply classify all this goal-oriented plasticity as "learning," then it becomes a basic principle of life that is continuous from very simple to very complex organisms. The fact that learning ability appears to be superior in complex life does not guarantee that it is entirely absent in simple life forms.

Intention before inheritance

A modest form of purposeful physiological learning featuring inter- and intracellular signaling, adaptive plasticity, and gene regulation could be a feature of all living systems no matter how simple. If so, it raises the possibility that this feature is not an evolved character, rather it may be a necessary prerequisite for ontogeny. It may be prohibitively unlikely, in environments that change significantly and unpredictably, for any surviving phenotype to develop unintentionally. If it is present in all life, it would appear that under the conditions on our planet biological natural selection might not be possible without it. This would mean some form of purposeful physiological learning was already present in the first life form and has been present in all life ever since. Such a universal "mental" property in all cells could be ruled out if we could locate a firm boundary between what type of cells can give rise to mental functions and which cannot. But if so, where does this boundary lie? Are neurons alone sufficient? Neurons and glial cells? Neurons, glial cells, peripheral nerves, and gut microbiota [11]? Even humans depend, to whatever slight degree, on an acquired community of simple, mostly prokaryotic microbiota to accomplish our superior cognition.

It is tautological that without survival and reproduction a lineage could not persist, but this does not prove that life must be exclusively dedicated to seeking it out. It is also logically possible that this could happen as a byproduct of pursuing another agenda. If we can accept that organisms can have experiences, accumulate memories, and gain knowledge, we have to recognize that these cannot possibly be "about" survival and reproduction because individual organisms never experience death or alternative rates of reproduction during their lifetimes. A universal form of purposeful physiological learning might present a possible motive, an alternative organizing principle for life, that could theoretically supercede survival and reproduction. Survival and reproduction could thus be seen as an incidental outcome in some subset of the systems that pursued this teleological aim, filtering extant lineages from extinct ones.

Problem-finding, not problem-solving

Learning is currently defined and tested in terms of problem-solving ability, or identified in incipient forms of the same such as sensitization, habituation, or associative learning [12-14]. This project is implicitly based on the assumption that learning is an evolved trait which arose late in the history of life to solve complex problems related to survival and reproduction. We have established above that this is possibly not the case. Fundamentally, problems must be identified before they can be solved. Because all organisms develop in responsive interaction with their environments, we cannot presuppose that inheritance defines the problems that are addressed by plasticity. As every struggling student knows, intelligence tests occur not in the cognitive domain of the subject but rather in the domain of the observer, which is a very different space indeed. Instead of recapitulating an heritable set of solutions to problems encountered by their ancestors, all organisms may be trying to actually understand the world themselves, which means finding their own problems in their own domains [15].

Unlike problem-solving, which presupposes a goal implanted by natural selection, understanding means open-ended experimentation to develop a sense of what entities and causal forces exist in one's surroundings [16, 17]. This would mean that all life, every living cell and also every whole organism, would contain within its phenotype some representation of the world that conflicts, in some respects, with experience. These conflicts present meaningful problems, significant areas which call out for investigation. The urge to understand the world (an umwelt) could thus serve as an intrinsic motivation for all living behavior, even morphological development. As strange as it may seem, this would mean for example that a lineage of cells in a developing embryo, as it differentiates into distinct somatic cells with specific functions, would be also developing into unique perspectives. Differentiated cells would be in effect forming stable opinions about how they each should live and behave as individuals and collectively, opinions based on experience, learning, and memory.

Understanding as the aim of life

The ability to contain a representation of the world inside one's phenotype and act on it is not necessarily a matter of consciousness. Consciousness in humans, for example, is largely extinguished during sleep even though sleep is considered critical for learning [18]. Although consciousness and focused attention certainly plays a role in the formation of new knowledge for humans, it would be hard to rule out the possibility that knowledge could form in biological structures incapable of consciousness, or the possibility that some rudimentary form of consciousness, though greatly attenuated in single cells, is coterminous with life [19]. Unconscious processes like dreaming play some role in learning, although the specifics are not well understood [20]. Like consciousness, there is currently no empirical test to determine whether organisms or cells contain representations of their umwelten, yet we assume that some biological structures (humans) certainly do. It is currently impossible to rule out on experimental grounds the possibility that other cells and organisms do as well.

If some life forms can develop perspectives, why not all of them? Understanding-seeking systems would be easy to mistake for survival-seeking genetic programs because the only such systems that could have persisted for long must incidentally also be compatible with a successful chain of material inheritance. It has become easy to manipulate DNA or manipulate phenotypes, document the effects of one on the other, and then conduct statistical analyses which ignore the bidirectional nature of the causal relationship between the two. This method of investigation has its strengths, but perhaps it is time to try to go further. It does not violate the objectivity of scientific inquiry to acknowledge that subjectivity may exist, and prove explanatory. It is quite difficult to imagine an umwelt from the point of view of another life form, and yet this is exactly what may be required to adequately explain a specific organism's actual development and behavior.

There must be a set of principles, though they are still unknown, that keeps life more organized than nonlife, in a statistically improbable state, far from thermodynamic equilibrium. Our predominant theories of biology assume that this organized appearance is due to heritable (read genetic or cytoplasmic) material influences. In its extreme form, this view sees control exerted by a plan or code received from evolution by natural selection as a form of transcendent intelligence [5, 20]. Since what is inherited is a matter of contingent historical accident compounded over trillions of generations, according to this account there is no reason to believe that any general principle could be extracted that might elucidate how learning (and thereby ontogeny) occurs. Life would be intractably complex and inscrutable because "the system and its historical antecedents are mechanistically and causally inseparable [21]".

If, however, we conclude that no inheritance would have been possible without some purposeful physiological learning, then there must be a relatively simple, general, endogenous mechanism according to which all living beings learn because it has been shared with all the ancestors of the first living cell. It may in fact be that this is what has allowed particulate inheritance to proceed. If there were no such learning then life might have been doomed to remain a simple, invariant self-replicating system like an ice crystal, dependent on a constellation of very specific environmental conditions for its existence and, like such crystals, unable to project reproductions of its morphology into the future beyond these very narrow confines. If this were true then genetic material, instead of being a condensed structure confined to a particular region and deployed in a highly selective, flexible way during ontogeny, would be in effect the entire morphology of the organism, again as it is for a crystal. Instead, life is quite unlike an inflexible crystalline solid. Life occurs largely in liquids, characterized by stochasticity and Brownian motion. The genome appears to be a specialized replicated tool, a library of templates for making RNA whose use is regulated, maintained, and reproduced by the entire cell [22].

The search for a mechanism

Any organism that learns must be a system with an open-ended constitution that makes it capable of informing its own internal organization by reading its external surroundings and incorporating them into itself functionally and purposefully. Rather than serving as a purposeless vehicle for DNA replication, all such organisms might be describable as entities (as we may consider ourselves to be) that are organized by a purposeful mission to absorb knowledge that they themselves perceive as meaningful. If a general biochemical mechanism was discovered to explain this behavior, it would obviate the need to posit supernatural origins for the presence of intention and purpose in the biosphere, and also obviate the need to deny such phenomena to preserve an attitude of scientific materialism.

What could be the general mechanism, common to all cell types on earth, that might produce this purposeful physiological learning, this epistolution? Could it be the networked connection of various oscillators and servomechanisms? In cybernetics, life was conceived of as a set of servos and oscillators driven by a program in the genome, but perhaps instead it is use and disuse in interactions with the umwelt itself that drives them. Gene expression (and everything that it leads to, including self-organization, development, and cognition) is controlled by an interaction between the phenotype and the environment. As Darwin himself presupposed, some form of use and disuse influences development [23]. In light of this new insight, principles might be discovered that could model epistolution in a network of oscillators linked by adjustable connections. Perhaps some form of program like this could interpret novel data and find new problems rather than acting simply as a readout of evolved, inherited signals. This type of algorithm, unlike all existing evolutionary algorithms, would have no intrinsic genotype-phenotype map and no preprogrammed survival or reproductive instinct, but would instead develop its form and its behavior strictly according to what it learned about the umwelt. If so, this would resolve the long-standing question of why and how biological genotypes lead to adaptive phenotypes.

A formalized model of epistolution might serve as a general principle explaining life. If so, this conceptual breakthrough would lead to more effective medical intervention, regenerative therapies, and eventually to the ability to design and build whole organisms fit for therapeutic, commercial, or creative purposes. It would also lead to the discovery of genuine creative knowledge by machines for the first time. In contrast to the current statistical mimicry [24] termed "artificial intelligence," machines programmed according to the (still currently unknown) principles of epistolution might gain causal understanding by inventing and testing their own subjective theories of what entities and forces exist in the world. Though not necessarily conscious, these would be the first artificial systems with the ability to develop their own subjective cognitive perspectives, their own agency. This might comprise a powerful new technology amplifying scientific, technological, aesthetic, and moral progress in many intellectual domains.

Even without a model of the specific mechanism that underpins epistolution, it may strengthen the Darwinian theory of evolution by natural selection to posit that this mechanism does indeed exist. Without such a mechanism, the theory of life contains no explanation for why adaptive plasticity is able to address problems that are not identical to those experienced by a lineage during the evolutionary past, why organisms actively influence their own conditions of selection to make it more likely that their lineage persists, and why genes are selectively turned on and off by epigenetic signaling that functionally adjusts to environmental conditions. The adaptive capacity of organisms is simply presupposed rather than explained by existing mathematical models of evolution by natural selection. Usually this is accomplished by surreptitiously defining a "gene" as the complete cause of a trait rather than as a particular sequence of nucleotides. Adding a supplemental purposive aim to the theory of life, one which can be pursued de novo by agents with perspectival subjectivity, resolves this problem. Although it does not exclude such an interpretation, this theoretical addition certainly does not require a supernatural or theistic claim of any sort. It merely requires the supposition that we have not yet discovered and understood every physical process that exists in biological systems.

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References:

1. Sultan, S.E., A.P. Moczek, and D. Walsh, *Bridging the explanatory gaps: What can we learn from a biological agency perspective?* Bioessays, 2022. 44(1): p. e2100185.
2. Okasha, S., *The Concept of Agency in Biology: Motivations and Meanings*. Biol Theory, 2024. 19: p. 6-10.
3. Noble, D., *The music of life : biology beyond the genome*. 2006, Oxford ; New York: Oxford University Press. xiii, 153 p.
4. Jablonka, E., M.J. Lamb, and A. Zeligowski, *Evolution in four dimensions : genetic, epigenetic, behavioral, and symbolic variation in the history of life*. Revised edition ed. Life and mind: philosophical issues in biology and psychology. 2014, Cambridge, Massachusetts ; London, England: A Bradford Book, The MIT Press. xii, 563 pages.
5. Oyama, S., *The ontogeny of information : developmental systems and evolution*. 1985, Cambridge ; New York: Cambridge University Press. ix, 206 p.
6. Patkova, I., et al., *Developmental plasticity of bacterial colonies and consortia in germ-free and gnotobiotic settings*. BMC Microbiol, 2012. 12: p. 178.
7. Matula, K., et al., *Phenotypic plasticity of Escherichia coli upon exposure to physical stress induced by ZnO nanorods*. Sci Rep, 2019. 9(1): p. 8575.
8. Fraebel, D.T., et al., *Evolution of Generalists by Phenotypic Plasticity*. iScience, 2020. 23(11): p. 101678.
9. Yi, X. and A.M. Dean*, Phenotypic plasticity as an adaptation to a functional trade-off*. Elife, 2016. 5.
10. Hug, S.M. and B.S. Gaut, *The phenotypic signature of adaptation to thermal stress in Escherichia coli*. BMC Evol Biol, 2015. 15: p. 177.
11. Meyer, K., et al., *Association of the Gut Microbiota With Cognitive Function in Midlife*. JAMA Netw Open, 2022. 5(2): p. e2143941.
12. Levin, M.*, Technological Approach to Mind Everywhere: An Experimentally-Grounded Framework for Understanding Diverse Bodies and Minds*. Front Syst Neurosci, 2022. 16: p. 768201.
13. Beigy, H. and M.R. Meybodi, *Cellular learning automata with multiple learning automata in each cell and its applications*. IEEE Trans Syst Man Cybern B Cybern, 2010. 40(1): p. 54-65.
14. Suhaimi, A., et al., *Representation learning in the artificial and biological neural networks underlying sensorimotor integration*. Sci Adv, 2022. 8(22): p. eabn0984.
15. Levin, M., *The Computational Boundary of a "Self": Developmental Bioelectricity Drives Multicellularity and Scale-Free Cognition*. Front Psychol, 2019. 10: p. 2688.
16. Popper, K.R., *The logic of scientific discovery*. 1959, New York,: Basic Books. 479 p.
17. Deutsch, D., *The beginning of infinity : explanations that transform the world*. 2011, New York: Viking. vii, 487 p.
18. Newbury, C.R., et al., *Sleep deprivation and memory: Meta-analytic reviews of studies on sleep deprivation before and after learning*. Psychol Bull, 2021. 147(11): p. 1215-1240.
19. Reber, A.S., et al., *The CBC theory and its entailments : Why current models of the origin of consciousness fail*. EMBO Rep, 2024. 25(1): p. 8-12.

20. Wamsley EJ, Stickgold R. *Memory, Sleep and Dreaming: Experiencing Consolidation*. Sleep Med Clin. 2011 Mar 1;6(1):97-108. doi: 10.1016/j.jsmc.2010.12.008. PMID: 21516215; PMCID: PMC3079906.
21. Branscomb, E., *Boltzmann's casino and the unbridgeable chasm in emergence of life research*. ArXiv, 2023. 2312.00932: p. 47.
22. Shapiro, J.A., *Evolution : a view from the 21st century*. 2011, Upper Saddle River, N.J.: FT Press Science. xi, 253 p.
23. Darwin, C., *On the origin of species by means of natural selection, Or, The preservation of favoured races in the struggle for life*. 1859, London: J. Murray
24. Jaeger, J., *Artificial intelligence is algorithmic mimicry: why artificial "agents" aren't (and won't be) proper agents*. ArXiv, 2023. 2307.07515.