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# A Phase-Based Framework for Respiration: Linking Biological Oscillators and Environmental Variability

Doha Lee

DohaTesla Lab, South Korea

doha.lee@dohateslalab.org

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## Abstract

Respiration and gas exchange are fundamental physiological processes that regulate metabolic homeostasis and autonomic function in living systems. Beyond their established biochemical roles, increasing evidence suggests that respiratory dynamics may also interact with environmental variability, including atmospheric and geophysical conditions, although the mechanisms and extent of such interactions remain under investigation.

In this study, we propose a theoretical framework that interprets respiration as a phase-modulated interface linking internal biological oscillators with external environmental dynamics. Within this formulation, respiratory activity is described in terms of phase relationships ( $\Delta\phi$ ), effective coupling strength ( $\kappa$ ), and information-related variability ( $\nabla I$ ), which can be approximated using measurable physiological and environmental proxies such as heart rate variability (HRV), respiratory rate, and environmental fluctuations.

Rather than asserting direct causality, this study integrates cross-domain observational evidence—including physiological synchronization patterns, behavioral responses in magnetosensitive species, and environmental variability—to examine potential associations between respiration and system-level coherence. Within this context, the circulation of key biogenic elements (carbon, hydrogen, oxygen, and nitrogen) is interpreted in terms of their roles in structural organization, energetic processes, and signal-related dynamics across biological and environmental systems.

Collectively, this framework provides a descriptive and hypothesis-generating model for analyzing respiration within a coupled organism–environment system. By situating respiratory dynamics within a broader phase-based context, the proposed approach offers a complementary perspective to existing physiological models and may support future investigations across biophysics, neurophysiology, and environmental health.

**Keywords:** Respiration; Phase synchronization; Biological oscillators; Environmental variability; Bioelectromagnetic coupling; Heart–brain interaction

## 1 Introduction

Respiration and gas exchange are fundamental physiological processes underpinning the survival and adaptation of aerobic organisms. Classical physiology primarily describes these functions as exchanges of oxygen and carbon dioxide between the lungs, bloodstream, and surrounding environment. In addition to their biochemical roles, respiration is closely linked to autonomic regulation, including interactions with cardiac dynamics and neural activity.

Recent studies across molecular biology, biophysics, and Earth sciences suggest that biological processes may operate within broader environmental contexts, where internal physiological dynamics interact with external variability such as light cycles, temperature, and geomagnetic activity [1, 2, 3]. These observations indicate that respiration may not function as an isolated process, but rather as part of a multiscale system involving interactions between internal biological oscillators and environmental conditions.

In this study, we propose a theoretical framework that interprets respiration as a phase-modulated interface linking biological systems with environmental variability. Within this formulation, respiratory dynamics are described in terms of phase relationships ( $\Delta\phi$ ), effective coupling strength ( $\kappa$ ), and information-related variability ( $\nabla I$ ), providing a tractable representation of synchronization and variability across scales. This approach is intended as a descriptive and hypothesis-generating model, complementing existing physiological and biophysical frameworks.

Within this context, the circulation of key biogenic elements—carbon, hydrogen, oxygen, and nitrogen—is interpreted in terms of their functional roles in structural organization, energetic processes, and signal-related dynamics in biological systems. Rather than treating these elements as purely chemical substrates, this perspective considers their potential contributions to system-level organization and regulation across interacting biological and environmental domains.

To explore this framework, we integrate findings from molecular biophysics, atmospheric science, and studies of magnetosensitive species, examining patterns of physiological synchronization and environmental variability across taxa, including aquatic organisms, plants, and humans. These observations are used to investigate potential associations between respiratory dynamics and system-level coherence, without assuming direct causality.

Collectively, this formulation situates respiration within a coupled organism–environment system, in which physiological processes may be influenced by and responsive to external variability. By framing respiration as part of a phase-based interaction structure, this study provides a complementary perspective for examining biological regulation, environmental interaction, and multiscale system dynamics.

## 2 Methods

This study adopts a theoretical and observational modelling approach to examine the coupled dynamics of respiration, gas exchange, and environmental variability. Rather than relying on experimental intervention, the framework is constructed through formal definition of variables, integration of observable physiological patterns, and analysis of system-level interactions across biological and environmental domains.

### 2.1 Conceptual and Mathematical Framework

Respiratory dynamics are represented using three primary variables: phase difference ( $\Delta\phi$ ), effective coupling strength ( $\kappa$ ), and information-related variability ( $\nabla I$ ). These variables provide a tractable representation of synchronization, interaction strength, and variability across biological and environmental systems.

Phase difference ( $\Delta\phi$ ) is defined as the relative temporal offset between internal biological oscillators (e.g., respiratory and cardiac rhythms) and external environmental variability. Effective coupling strength ( $\kappa$ ) represents the degree of synchronization between these systems, while  $\nabla I$  reflects fluctuations in physiological and environmental signals, approximated through variability and entropy-related measures.

### 2.2 Physiological and Observational Proxies

To operationalize the theoretical framework, commonly observed physiological indicators were used as proxies for system dynamics. Heart rate variability (HRV) and respiratory patterns were used to represent internal oscillatory behavior, while environmental variability (e.g., temperature fluctuations, geomagnetic activity) was considered as external input.

These indicators were not treated as direct causal measurements, but as observable correlates that allow approximation of phase relationships and coupling dynamics within the proposed framework.

### 2.3 Analytical Approach

The analysis focuses on identifying patterns of synchronization and variability across biological and environmental domains. Temporal alignment, correlation structures, and variability patterns were examined to assess potential relationships between internal physiological dynamics and external environmental fluctuations.

Rather than asserting direct causal mechanisms, the approach is descriptive and hypothesis-generating, aiming to characterize system-level coherence and interaction patterns.

### 2.4 Scope and Limitations

This study is based on theoretical formulation and observational interpretation, without direct experimental manipulation. As such, the framework is intended to provide a conceptual and analytical basis for future empirical validation. The results should therefore be interpreted as indicative of potential associations rather than definitive causal relationships.

## 3 Results

### 3.1 Network Synchronization of Respiration and Gas Exchange in Living Systems

Within the proposed framework, respiration can be interpreted as a periodic synchronization process linking the organism with its surrounding environment. Rather than functioning solely as an exchange of oxygen and carbon dioxide, respiratory dynamics are associated with coordinated temporal patterns across physiological systems.

Across diverse taxa—including birds, fish, and plants—variations in environmental conditions such as atmospheric or aquatic composition are associated with adjustments in internal biological rhythms, including cardiac activity, neural oscillations, and cellular dynamics. These observations are consistent with the interpretation that respiration operates within a multiscale system involving interactions between internal oscillators and external variability.

In humans, cardiopulmonary dynamics primarily regulate gas exchange; however, respiratory and cardiac rhythms also exhibit sensitivity to environmental fluctuations. Within this framework, such variability can be interpreted as contributing to phase entrainment processes, forming a distributed network of bioelectrical and physiological interactions.

These observations are consistent with previously reported empirical patterns of physiological and environmental variability.

### 3.2 Circulation between Body and Environment: Phase Coupling and Resonance

The sensitivity of organisms to environmental variability, including geomagnetic and atmospheric fluctuations, can be interpreted within a phase-synchronization framework. Observations across taxa—including birds, fish, and insects—indicate that behavioral patterns such as migration and seasonal timing are associated with environmental cues.

Such interpretations align with observed associations between environmental cues and biological responses reported across multiple taxa.

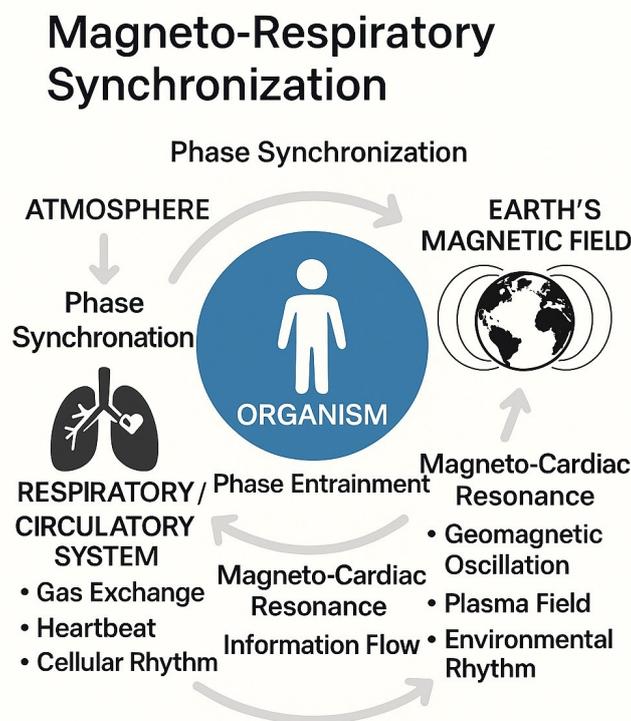
Within the proposed model, these responses are described as manifestations of phase coupling between internal biological systems and external environmental dynamics. This interpretation does not assume direct causality, but instead emphasizes the role of synchronization and adaptive alignment across scales.

In this context, the Heart–Brain Axis Matrix (HBAM) is introduced as a conceptual model describing interactions between cardiac, neural, and environmental dynamics [4]. Within this framework, cardiac and neural systems are treated as coupled oscillatory components that may exhibit phase alignment with environmental variability.

Rather than treating emotion and memory as purely localized biochemical processes, this model interprets them as system-level phenomena associated with dynamic physiological states and temporal coordination across biological networks.

At the cellular level, respiratory oscillations are considered to contribute to alignment with environmental variability, potentially influencing behavioral and physiological patterns over time.

As illustrated in Figure 1, the synchronization between respiratory dynamics and environmental variability can be represented as a phase-coupled network linking organism-level processes with broader environmental systems.



**Figure 1:** Schematic representation of phase synchronization between the organism, atmospheric environment, and geomagnetic variability. The respiratory and circulatory systems are shown as mediating gas exchange and physiological rhythms, while environmental fluctuations contribute to phase entrainment and system-level coordination. Arrows indicate bidirectional interactions across biological and environmental domains.

### 3.3 Circulation of the Four Elements: An Informational and Energetic Network Perspective

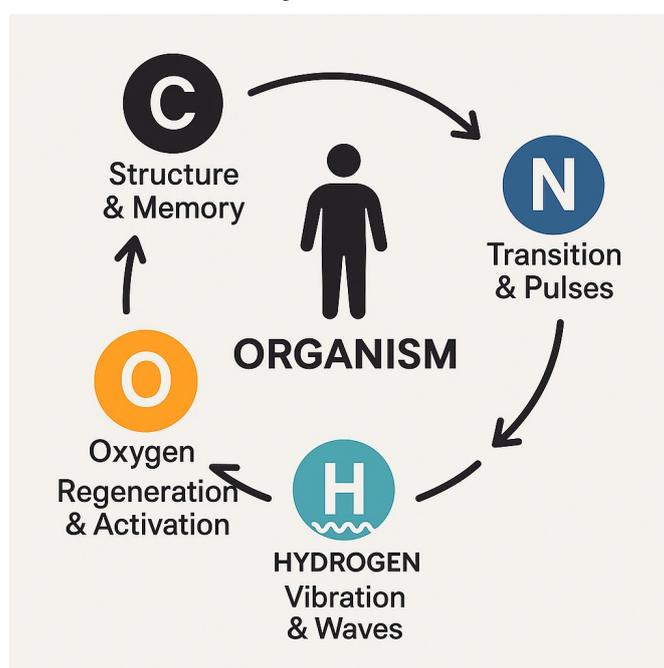
Within the proposed framework, the four principal biogenic elements—carbon, hydrogen, oxygen, and nitrogen—can be interpreted as contributing to distinct informational and energetic roles within biological systems.

Carbon is associated with structural organization and long-term stability of biological systems, forming the basis of complex molecular architectures. Hydrogen, due to its physicochemical properties, is interpreted as contributing to dynamic interactions and signal propagation within biological and aqueous environments. Oxygen is primarily involved in metabolic processes and energy transformation, supporting continuous physiological activity. Nitrogen is associated with regulatory and adaptive processes, particularly in relation to biochemical cycling and environmental responsiveness.

Rather than functioning independently, these elements are considered to participate in an integrated network of interactions across cellular, organismal, and environmental levels. This perspective suggests the presence of coordinated flows of energy and information across multiple biological scales.

These interpretations are consistent with observed patterns of elemental cycling and metabolic organization across diverse biological systems. This interpretation is intended as a conceptual abstraction rather than a direct biochemical redefinition.

As depicted in Figure 2, the four elements—carbon, hydrogen, oxygen, and nitrogen—can be represented as participating in a continuous cycle of interaction between organism and environment.



**Figure 2:** Conceptual representation of the circulation and interaction of four key biogenic elements—carbon, hydrogen, oxygen, and nitrogen—within biological and environmental systems. Each element is associated with functional roles in structural organization, dynamic interactions, metabolic processes, and regulatory adaptation. The diagram illustrates their integrated contribution to system-level coordination across organism and environment.

### 3.4 Bacteria, Gas Distribution, and Nonlinear Ecological Responses

Environmental variability, including changes in geomagnetic conditions, atmospheric composition, and anthropogenic influences, has been associated with shifts in both marine and terrestrial ecosystems. For example, large-scale ecological events such as whale strandings and alterations in marine population dynamics have been discussed in relation to geomagnetic variability, acoustic disturbances, and changes in dissolved gas composition.

Marine bacterial communities exhibit adaptive responses to environmental gradients, including variations in oxygen availability and gas distribution. These responses involve dynamic reorganization of metabolic processes and population structures, reflecting flexible adaptation to changing environmental conditions.

Within this framework, such dynamics can be interpreted as continuous adjustments across multiple states rather than discrete transitions, emphasizing the importance of variability and responsiveness in ecological systems.

The increasing prevalence of jellyfish in certain marine environments can be interpreted as reflecting shifts in ecosystem structure under changing environmental conditions. Rather than attributing a singular causal mechanism, this pattern may be associated with broader changes in environmental variability, resource distribution, and system-level adaptation.

These observations suggest that biological systems may exhibit nonlinear responses to environmental perturbations, consistent with the proposed framework of phase-dependent and multiscale interaction dynamics.

### 3.5 Cross-Resonance among Biological and Environmental Systems: Entropy and Adaptation

The interaction between geomagnetic variability, atmospheric conditions, and biological systems can be interpreted as a coupled, multiscale network. Environmental fluctuations, including changes in geomagnetic activity and atmospheric composition, have been associated with shifts in collective biological behavior, such as migration patterns, population dynamics, and ecological transitions.

In humans, environmental variability has been linked to measurable physiological responses, including changes in neural activity, autonomic regulation, and sensory processing. Within this framework, such responses can be interpreted as adaptive adjustments rather than direct deterministic effects.

All living systems operate in close association with microbial ecosystems, which play a central role in metabolic regulation and environmental responsiveness. These microbial networks contribute to dynamic adaptation across scales, supporting flexibility in response to environmental perturbations.

Within the proposed framework, these interactions are described in terms of phase-dependent alignment and variability across biological and environmental systems. This perspective emphasizes the role of coordinated dynamics in adaptive processes and evolutionary change. These findings are interpreted within the proposed theoretical framework.

### 3.6 Geomagnetic and Environmental Variability in Biological Regulation and Renewal

Environmental variability, including fluctuations in geomagnetic intensity and atmospheric conditions, has been associated with changes in ecosystem structure, population dynamics, and biological rhythms. Such changes may include both destabilization and reorganization processes within biological systems.

In certain ecological contexts, shifts in environmental conditions have been linked to recovery or restructuring of biological populations, suggesting that variability can contribute not only to disruption but also to adaptation and renewal.

Within this framework, biological systems—including microbial communities—are understood to exhibit dynamic reorganization in response to environmental changes. These processes involve adjustments in metabolic activity, population structure, and system-level coordination.

Rather than proceeding through strictly linear pathways, these observations support the interpretation of evolution as a nonlinear and adaptive process, characterized by variability, resilience, and reconfiguration across scales.

This perspective suggests that biological regulation, memory-related processes, and adaptive behavior may be influenced by multiscale interactions between internal physiological dynamics and external environmental variability.

### 3.7 Sensory, Energetic, and Rhythmic Synchronization in Mammals

Across diverse terrestrial ecosystems—including African savannas and tropical rainforests—mammals (e.g., buffalo, lions, gorillas, elephants) deploy highly specialized sensory systems, particularly the vomeronasal (Jacobson's) organ and olfactory pathways, to optimize resource localization, environmental awareness, and coordinated group behavior. Herbivores such as buffalo utilize chemosensory mechanisms to detect mineral sources (notably sodium salts) and water, influencing migratory dynamics at the population level. Carnivores similarly rely on olfactory cues to detect prey-related signals, enabling energy-efficient hunting strategies.

These sensory processes involve integrated interactions across neural, physiological, and behavioral systems. Environmental cues—including water, minerals, and chemical signals—are closely linked to modulation of neural activity and behavioral responses, including those associated with dopaminergic regulation and motivation.

Within the proposed framework, these interactions may be interpreted as coordinated dynamics across sensory, physiological, and environmental domains, contributing to system-level synchronization and adaptive behavior. In this context, dopaminergic processes, rather than functioning solely as transient reward signals, may be conceptualized as sustained bioelectrical activators—referred to here as a “dopaminergic spark,” as a conceptual descriptor of sustained bioelectrical activation supporting persistent modulation of physiological and neural activity across distributed biological systems.

These findings are interpreted within the proposed theoretical framework.

Remarkably, certain mammals such as cheetahs exhibit extreme physiological adaptations characterized by rapid energy expenditure followed by extended recovery phases. A cheetah can expend nearly its entire metabolic reserve during a single high-speed chase, yet may require prolonged recovery even in the absence of immediate nutritional replenishment. This observation suggests the involvement of complex endogenous regulatory mechanisms beyond conventional caloric models.

Within this framework, such phenomena may be conceptualized as a form of “nitro-plasma cardiodynamics,” describing a transient, high-energy physiological state involving nitrogen-related metabolic activation, nitric oxide (NO)-mediated signaling, and systemic bioelectrical coordination. In this state, rapid physiological activation is followed by a refractory recovery phase, potentially reflecting the restoration of internal metabolic and regulatory balance.

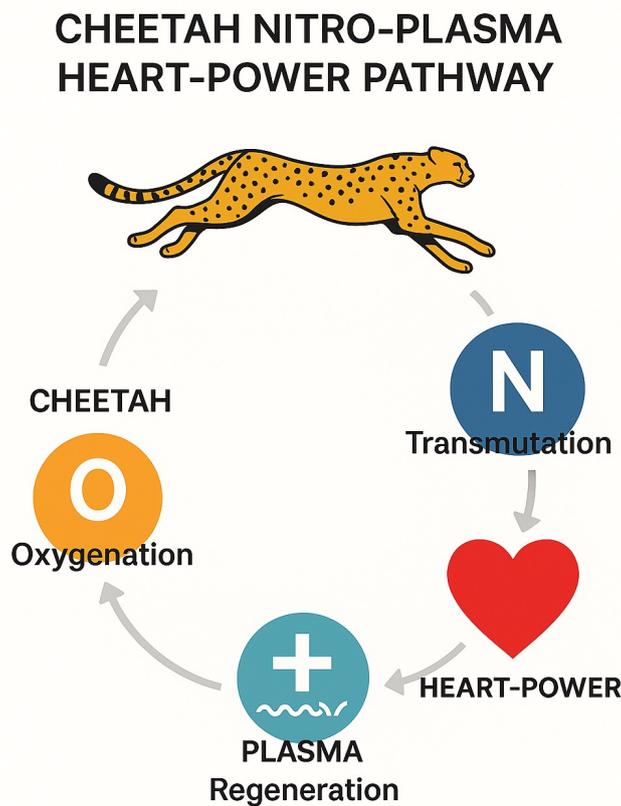
Rather than attributing performance solely to caloric input, this perspective emphasizes the role of integrated physiological regulation, including metabolic, neural, and bioelectrical processes operating across multiple scales. These dynam-

ics suggest that biological performance and recovery may involve coordinated interactions between internal physiological states and broader environmental conditions.

Furthermore, this framework suggests that biological motivation may emerge not only from neurochemical signaling but also from sustained bioelectrical and physiological activation. The pursuit of targets—such as prey, resources, or information—may involve continuous modulation of internal system dynamics, rather than isolated reward-triggered events.

Collectively, these observations support the interpretation that biological systems operate through coordinated, multiscale dynamics involving sensory input, physiological regulation, and environmental interaction. Such dynamics may be described in terms of phase alignment and resonance-like behavior across biological systems.

As illustrated in Figure 3, the cheetah example represents a conceptual pathway linking oxygen utilization, nitrogen-related metabolic processes, plasma-like energetic dynamics, and cardiac output, highlighting coordinated physiological activation and recovery processes.



**Figure 3:** Conceptual illustration of a physiological pathway associated with extreme metabolic performance in mammals, exemplified by the cheetah. The diagram represents interactions between oxygen utilization, nitrogen-related metabolic processes, plasma-like energetic dynamics, and cardiac output. This model highlights coordinated physiological activation and recovery processes beyond simple caloric input.

### 3.8 Case Study: Human Longitudinal Wearable Data

#### Methods / Disclosure

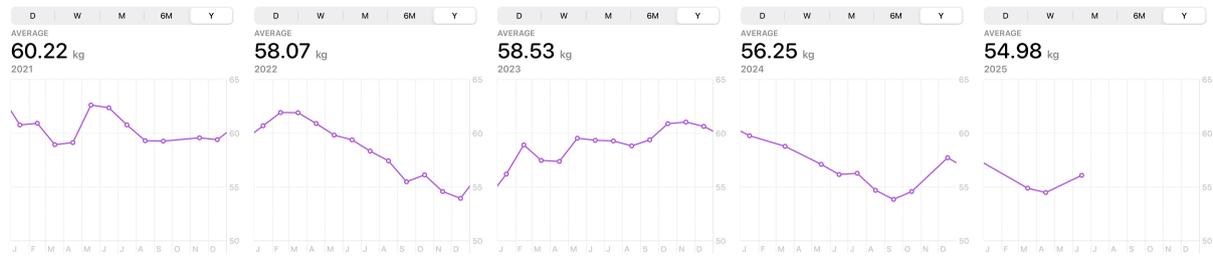
This case study is based on retrospective, self-tracked longitudinal data collected by the author under naturalistic, non-experimental conditions. All measurements were obtained during daily life without controlled intervention.



**Figure 4:** Longitudinal wearable activity data (Move, Exercise, Stand; 2021–2025) illustrating year-specific patterns of human activity. Variations correspond to shifts in lifestyle context, including office work, exam preparation, and research immersion, suggesting structured modulation of behavioral rhythms.

Longitudinal wearable activity data (Move, Exercise, Stand; 2021–2025) reveal distinct annual patterns in human movement behavior. These variations correspond to changes in lifestyle context, including office work (2021–2023), exam preparation (2024), and intensive research immersion (2025).

Rather than being random, these structured variations suggest that human activity patterns are modulated by environmental context, behavioral demands, and system-level regulation. These patterns may also be interpreted as reflecting a form of structured trajectory modulation in human behavioral rhythms, potentially analogous to structured navigation-like processes observed in other biological systems



**Figure 5:** Annual trends in average body weight (2021–2025) derived from longitudinal self-tracking data. Periods of weight reduction appear associated with phases of sustained system engagement, while seasonal fluctuations suggest potential coupling with environmental or physiological cycles.

Analysis of body weight trends indicates that reductions in body weight were more pronounced during periods of sustained engagement and systemic physiological activation (e.g., 2022, 2024, 2025), compared to periods characterized primarily by increased physical activity alone.

These patterns may reflect structured trajectory modulation in behavioral rhythms, potentially contributing to shifts in metabolic activity and energy expenditure through integrated physiological responses.

From this perspective, body weight is not a fixed or purely behavior-driven trait, but a dynamic outcome of organism–environment interaction. Individuals may exhibit varying degrees of sensitivity to environmental demands, and increased adaptive load may lead to shifts in energy allocation strategies, including enhanced energy storage.

Seasonal patterns were also observed, including transient increases in body weight during late spring and summer (May–August). These fluctuations may reflect physiological regulation processes such as fluid balance, thermoregulation, or seasonal metabolic adaptation.

Importantly, these findings suggest that body weight dynamics cannot be fully explained by caloric intake or voluntary behavior alone. Instead, they may reflect interactions between environmental conditions and organism-level regulatory systems, potentially involving broader organism–environment coupling processes.

From this perspective, adipose tissue may be interpreted not only as an energy storage system, but also as an adaptive buffering layer that integrates and stabilizes physiological responses under varying environmental and regulatory demands.

Importantly, these findings challenge simplified value judgments that classify body weight states as inherently “optimal” or “pathological,” and instead support a view of the body as a dynamically adapting system responding to environmental and physiological demands.

These observations suggest that body weight fluctuations are not solely determined by individual-level causes, but emerge from interactions between environmental variability and systemic physiological regulation.

These findings are interpreted within the proposed theoretical framework.

**Limitations**

This case study is limited by its single-subject design and observational nature. As such, the findings should be considered exploratory and hypothesis-generating rather than generalizable. Nevertheless, the longitudinal structure and integrative perspective provide a proof-of-concept for examining human biological rhythms in relation to environmental and regulatory dynamics.

## 4 Discussion

### 4.1 Organic Life Networks and Geomagnetic Synchronisation

This study suggests that life processes across diverse biological taxa—including birds, fish, insects, mammals, plants, and microbial systems—operate within dynamically coupled environmental systems. Observations across these domains indicate that biological activity may exhibit sensitivity to environmental variability, including geomagnetic and atmospheric fluctuations [2, 5, 3].

Within this context, such interactions may be interpreted through a phase-based framework, in which biological systems exhibit resonance-like synchronization with environmental dynamics across multiple scales. Sensory-driven environmental interactions—such as those observed in mammals (e.g., buffalo, elephants, and gorillas) through specialised systems including the vomeronasal organ—demonstrate the capacity of organisms to detect chemical gradients, resource distributions, and environmental cues that influence navigation, foraging, and coordinated behaviour [6].

These phenomena may also be viewed as reflecting structured ecological memory processes, in which biological systems encode and respond to environmental information over time. Similar principles are observed across taxa, where insects, birds, and mammals respond to combinations of chemical, vibrational, and electromagnetic signals, enabling adaptive behaviours across ecological contexts [7, 8].

The coupling among plants, insects, bacteria, and atmospheric processes is further supported by established biogeochemical cycles, including nitrogen fixation, atmospheric ionisation processes, and large-scale ecosystem interactions [9, 10]. Within the proposed framework, these interactions may be conceptualized as components of a broader phase-network system linking biological, environmental, and atmospheric dynamics, providing a unifying structure for interpreting multiscale organism–environment coupling.

### 4.2 Bacteria, Memory, and Entropy Regulation

Bacteria play a central role in mediating biochemical and ecological processes across the biosphere. Their metabolic versatility—including nitrogen fixation, nitrate reduction, and participation in global nutrient cycles—positions them as key regulators of environmental and physiological dynamics [9].

From a systems perspective, bacterial activity may be interpreted as contributing to the regulation of biological rhythms, adaptive processes, and environmental responsiveness. Previous studies suggest that biological systems exhibit oscillatory and field-sensitive properties across multiple scales, supporting the interpretation of coordinated systemic behaviour [11, 12].

Under conditions of environmental stress, microbial communities exhibit dynamic reorganization, supporting ecosystem resilience and transition. Within the proposed framework, these dynamics may be conceptualized as part of broader processes governing systemic adaptation and variability.

### 4.3 Nature, Humans, and Information: The Future of Living Networks

Humans are embedded within complex biological and environmental systems, with physiological processes influenced by interactions among neural, metabolic, and environmental factors. Environmental signals—including circadian, electromagnetic, and chemical inputs—have been associated with modulation of biological rhythms and neural activity [1, 13].

Environmental disruption, including ecosystem imbalance and atmospheric change, has been associated with effects on biological systems across multiple scales, from microbial ecology to organism-level physiology [14].

These observations suggest that human health and behaviour may be influenced by interactions between environmental variability and systemic physiological regulation. Neurophysiological processes such as dopaminergic signalling further contribute to behavioural modulation and adaptive responses [15].

Collectively, these findings support a perspective in which biological systems operate through coordinated, multiscale phase interactions, rather than isolated biochemical processes. This phase-network perspective suggests that life may be understood as an emergent property of dynamic synchronization across biological, environmental, and informational domains.

This integrative framework provides a conceptual basis for reinterpreting biological regulation as an emergent property of organism–environment coupling, offering a new perspective on physiology, adaptation, and the organization of living systems across scales.

## 5 Conclusion

This study proposes an integrative framework for understanding the real-time synchronization and nonlinear evolutionary trajectories of living systems, environmental matrices, and the Earth's geomagnetic field, with a particular focus on the

coupled dynamics of respiration, gas exchange, and environmental variability.

Within this framework, respiration may be interpreted not only as a process of gaseous exchange, but also as a coordinating interface within a broader, multiscale system linking organisms, microbial processes, atmospheric dynamics, and geomagnetic conditions.

The four fundamental elements of life—carbon, hydrogen, oxygen, and nitrogen—may be understood not only as molecular substrates, but also as components of distributed processes involving energy transfer, structural organization, and system-level regulation. Across diverse biological taxa, environmental variability—including changes in geomagnetic activity, atmospheric composition, and ecological conditions—has been associated with modulation of biological rhythms, behavioral patterns, and physiological responses.

Bacteria are considered central mediators within these systems, contributing to biochemical cycling and ecological regulation across multiple scales. Their roles in processes such as nitrogen cycling and metabolic adaptation highlight their importance in maintaining continuity and enabling transitions within biological and environmental systems.

From this perspective, ecological resilience may be understood as an emergent property of coordinated interactions among organisms, microbial systems, environmental conditions, and atmospheric processes, within which humans are intrinsically embedded.

### Future Directions and Implications

Future research should aim to quantitatively investigate the relationships between environmental variability, atmospheric composition, ecological change, and biological regulation across scales. Integrating observational data, computational modeling, and interdisciplinary approaches may provide further insight into system-level interactions linking physiology, environment, and adaptive processes.

### Clinical Implications

Understanding multiscale interactions among physiological regulation, environmental variability, and systemic coordination may inform new approaches to studying neurophysiological, cardiovascular, and metabolic conditions. These perspectives may contribute to the development of integrative frameworks for health and resilience in dynamic environments.

### Policy Implications

Given the interdependence of biological systems and environmental conditions, efforts to preserve ecological balance, biodiversity, and atmospheric stability may have significant implications for long-term system resilience. Recognizing the interconnected nature of these processes may support more comprehensive approaches to environmental policy, public health, and sustainability.

This work contributes to the development of a phase-network perspective on life, in which biological systems are understood as dynamically synchronized entities within a coupled organism–environment system

### Declaration

**Availability of data and materials.** All data and materials relevant to this study are included within the article.

**Funding.** This research received no external funding and was conducted independently by the author.

**Author contributions.** D. Lee (Doha Lee) conceived the study, performed the analysis, prepared the manuscript, and approved the final version.

**Competing interests.** The author declares no competing interests.

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