

Beyond Mourning: Biological Spectrum Theory of Grief Coherence (BST-GC) and the Multiscale Reorganization of Living Systems after Loss

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How to cite this paper: Alabdulgader, A. (2026) Beyond Mourning: Biological Spectrum Theory of Grief Coherence (BST-GC) and the Multiscale Reorganization of Living Systems after Loss. *Open Journal of Psychiatry*, 16, 296-321.

<https://doi.org/10.4236/ojpsych.2026.164023>

Received: September 1, 2026

Accepted: October 9, 2026

Published: October 12, 2026

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Abstract

Mourning-like behaviors documented across socially complex species, including elephants, primates, and corvids, are remarkably structured, coordinated, and temporally extended, yet their underlying biological mechanisms remain incompletely understood. Existing explanations emphasize emotional attachment, stress responses, vigilance, or social cognition but do not fully account for the collective physiological reorganization that follows the loss of a socially integrated individual. This theoretical and hypothesis-generating manuscript introduces the Network Coherence Collapse (NCC) hypothesis within the Heart-Based Resonant Field (HBRF) framework and extends it into the Biological Spectrum Theory of Grief Coherence (BST-GC), a multiscale systems framework of biological adaptation following irreversible loss. Social organisms are conceptualized as weakly coupled nonlinear oscillatory networks in which sustained interaction promotes partial physiological synchronization. Biological death is proposed to represent the extinction of an active coherence generating node rather than the persistence of postmortem signaling, producing transient phase dispersion, increased entropy, disruption of network synchronization, and progressive attractor reorganization among surviving organisms. Mourning associated behaviors, including aggregation, circling, guarding, immobility, vocal modulation, and recurrent visitation, are consequently interpreted as adaptive network level processes that facilitate autonomic recoupling and restoration of coherence. BST-GC further proposes that these responses reflect redistribution of biological organization across nested domains spanning cellular, physiological, organismal, social, and ecological scales. BST-GC is proposed as a comparative framework for socially complex vertebrates, with mammalian physiology providing its principal mechanistic foundation and corvids serving as a phylogenetically distinct avian model for

testing whether analogous network-level responses to social loss occur across divergent vertebrate systems. The framework remains explicitly constrained by established electrophysiology, nonlinear dynamical systems theory, thermodynamic irreversibility, and classical electromagnetic principles, rejecting postmortem field persistence or metaphysical continuity. By generating quantitative, falsifiable predictions concerning synchronization dynamics, entropy trajectories, network topology, and recovery following node removal, BST-GC establishes a testable systems framework that reframes grief as a measurable process of multiscale biological reorganization rather than solely an emotional or behavioral phenomenon.

Keywords

Biological Spectrum Theory of Grief Coherence (BST-GC), Heart-Based Resonant Field Theory (HBRF), Comparative Thanatology, Social Neurocardiology, Network Coherence Collapse, Nonlinear Dynamical Systems, Physiological Synchronization, Heart Rate Variability, Complex Adaptive Systems, Multiscale Biological Coherence

1. Empirical Background: Structured Mourning-Like Behaviors

Across phylogenetically distant social biological systems, convergent post-mortem behavioral repertoires have been documented to exhibit patterned, non random, and temporally extended structure following the death of a conspecific. These behaviors exceed simple startle or avoidance reactions and display organized motor, autonomic, and social coordination consistent with higher-order integrative processing. In **elephants** (family *Elephantidae*), field observations describe: repeated and highly selective trunk exploration of skeletal remains, particularly cranial and tusk regions, prolonged silent immobility in close spatial proximity to the corpse, recurrent visitation of death sites over extended temporal intervals and slow deliberate circumambulatory locomotor patterns around remains [1] (**Figure 1**).

In chimpanzees (*Pan troglodytes*), responses to the death of a conspecific can involve prolonged and attentive engagement with the body, highlighting both social awareness and emotional attunement. As illustrated in **Figure 2**, group members may observe the deceased closely, maintaining a period of quiet vigilance and proximity. Researchers or caregivers handling the body often elicit a clear, focused interest from the group, demonstrating behaviors such as sustained visual attention, minimal vocalization, and coordinated positioning relative to the deceased. These responses suggest that chimpanzees are sensitive to the absence of a socially significant individual, with mourning behaviors representing a temporary reorganization of group attention and movement dynamics rather than simple curiosity. Such behaviors underscore the complexity of primate social cognition and

the distributed, network-level impact of loss within a cohesive social system [2].



Figure 1. Elephants at a deceased conspecific. Elephants exhibiting mourning behavior at the body of a deceased conspecific, reflecting adaptive recalibration within their socially coupled oscillatory network (Photograph source: Reproduced under [CC BY 4.0/CC BY-SA/public-domain status/permission from copyright holder], which permits publication and reuse subject to the stated terms).



Figure 2. Chimpanzees observing a deceased group member. Chimpanzees observing the removal of a deceased group member, reflecting network-level recalibration in socially coupled biological oscillators (Photograph source. Reproduced under [CC BY 4.0/CC BY-SA/public-domain status/permission from copyright holder], which permits publication and reuse subject to the stated terms).

In **corvids** (family *Corvidae*), observations reveal: rapid collective aggregation at sites containing conspecific carcasses, intensified and coordinated vocalization bursts and repetitive circular or orbital flight trajectories above the location [3] (**Figure 3**). Conventional ethological interpretations typically attribute these phenomena to adaptive learning, predator inspection, attachment disruption, stress-mediated arousal, or socially facilitated vigilance. While each of these mechanisms likely contributes at the proximate behavioral level, such models remain largely organism centric and neurochemical in emphasis. They do not explicitly address the possibility that these behaviors may reflect perturbations in distributed, inter-individual regulatory dynamics operating at the level of energetic socially coupled physiological networks.



Figure 3. Corvid post-mortem social response: A live crow exhibits intense vocalization and positioning above a deceased conspecific, reflecting coordinated behavioral patterns that may extend beyond simple startle or avoidance. (Photograph source: Reproduced under [CC BY 4.0/CC BY-SA/public-domain status/permission from copyright holder], which permits publication and reuse subject to the stated terms.).

Although the physiological foundation of BST-GC is derived primarily from mammalian studies, the framework is not intended to be restricted to mammals. Corvids provide an important comparative avian model because they exhibit complex social organization, persistent social relationships, coordinated group behavior, and structured responses to conspecific death. Their inclusion does not imply identical mammalian and avian neurophysiology. Rather, corvids provide a phylogenetically distant test of whether higher-order dynamical features proposed by BST-GC—such as disruption of group organization following loss of a socially integrated member, spatial aggregation, coordinated vocalization, altered interaction topology, and subsequent network re-stabilization may emerge across distinct vertebrate physiological architectures. Avian inclusion therefore broadens the comparative and falsifiable scope of BST-GC while preserving mammalian physiology as its principal mechanistic foundation.

2. HBRF Reframing: Mourning as Network Level Coherence Destabilization

Within the Heart-Based Resonant Field Theory (HBRF), social organisms are conceptualized not merely as independent neural processors but as bioelectromagnetically active oscillatory systems capable of transient phase coupling through cardiac-mediated electromagnetic field interactions. The heart, as the dominant macroscopic oscillator within the organism, generates rhythmic electromagnetic fluctuations that participate in intra-organismic integration and potentially contribute to inter-organismic entrainment under conditions of sustained social proximity [4]. Within the Heart-Based Resonant Field (HBRF) framework, extrapolation from humans to other mammals is scientifically defensible because the underlying mechanism is not uniquely human but rooted in conserved mammalian cardiac electrophysiology. All mammals possess homologous sinoatrial pacemaker structures, coordinated myocardial depolarization, and measurable electrocardiographic activity; synchronized ionic charge movement in excitable cardiac tissue necessarily generates electric and magnetic fields according to fundamental electromagnetic principles described by James Clerk Maxwell [5]. The structural and functional architecture of the mammalian heart is highly conserved, as detailed in standard physiological references such as Textbook of Medical Physiology by Arthur C. Guyton and John E. Hall, indicating that electromagnetic field generation is an inherent property of mammalian cardiac function rather than a species-specific phenomenon [6]. Moreover, autonomic oscillatory dynamics, including respiratory sinus arrhythmia and vagally mediated heart rate variability, are evolutionarily conserved across mammals, as demonstrated by Paul Grossman and Edmund W. Taylor, establishing that the oscillatory substrate central to HBRF is comparative rather than anthropocentric. Because larger mammals possess greater myocardial mass and depolarization volume, basic biophysical scaling principles predict that cardiac electromagnetic field magnitude may increase with heart size, further supporting cross species plausibility. Thus, HBRF does not posit a uniquely human electromagnetic phenomenon; it extends established principles of mammalian electrophysiology, oscillator dynamics, and conserved autonomic regulation to socially coupled systems, making its application to non human mammals a theoretically grounded and biologically coherent generalization rather than an unwarranted extrapolation. From a dynamical systems perspective, bonded social groups may be described as assemblies of weakly coupled nonlinear oscillators exhibiting partial phase synchronization across autonomic variables, including heart rate variability (HRV), respiratory rhythms, and affect-linked neurocardiac patterns. *Repeated interaction strengthens statistical coherence among these oscillatory signatures, stabilizing a distributed network attractor state* [7]. *Biological death represents an abrupt and irreversible cessation of cardiac oscillatory coherence in the deceased organism. The individual ceases to function as an active node within the socially entrained system. Under our HBRF mechanistic framework, this constitutes not merely the loss of a behavioral partner but the removal of a coherence stabilizing oscillator from a dynamically coupled network* [8]. In non-

linear dynamical and complex network systems, abrupt removal of a highly coupled node may lead to loss of phase synchrony among previously coordinated elements, transient destabilization of metastable attractor configurations, increased dynamical variability, and subsequent reorganization toward a new equilibrium state [8] [9]. The structured “mourning-like” behaviors described above may therefore be interpreted as *emergent manifestations of network recalibration* rather than solely affective or cognitive reactions in isolated individuals (Figure 4).

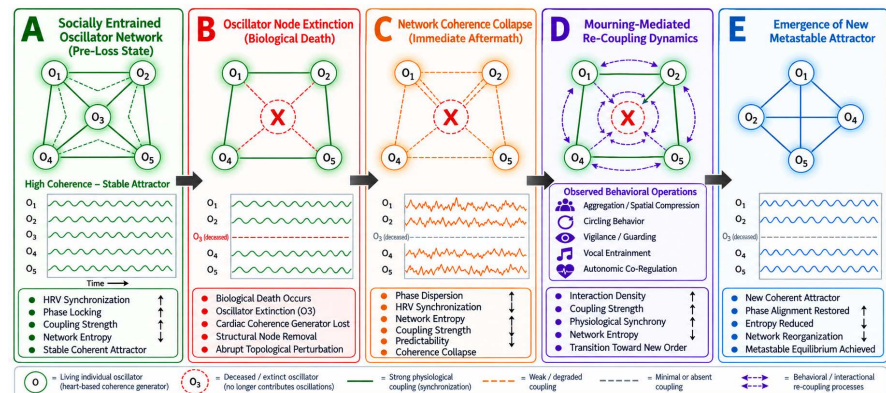


Figure 4. Schematic summary of the Network Coherence Collapse hypothesis within the Alabdulgader HBRF framework. (A) Before loss, socially coupled organisms (O1-O5) show partial synchronization of cardiac-mediated rhythms, with strong coupling, low entropy, and a stable coherent attractor. (B) Biological death of one member (O3) extinguishes one coherence-generating oscillator and removes a network node. (C) The surviving network shows phase dispersion, reduced HRV synchronization and coupling strength, increased entropy, and reduced predictability. (D) Mourning-associated behaviors, including aggregation, circling, vigilance/guarding, vocal entrainment, and autonomic co-regulation, are proposed to increase interaction density and facilitate re-coupling. (E) The network reorganizes into a new topology, partially restores synchrony, reduces entropy, and settles into a new metastable attractor rather than returning to the pre-loss state.

3. Grief as Network-Level Dynamical Reorganization: A Heart-Based Resonant Field Perspective on Socially Coupled Biological Oscillators

From this standpoint, circumambulatory movement, such as the slow deliberate circling observed in elephants or the orbital flight trajectories documented in corvids, may be interpreted as spatially mediated recoupling dynamics, in which motor behaviors increase proximity dependent sensory and physiological interaction among surviving group members, thereby enhancing the probability of renewed interindividual synchronization. Collective aggregation at the site of death may further amplify autonomic coregulation, facilitating partial restoration of disrupted phase relationships across heart rate variability, respiratory rhythms, and affect linked neurocardiac oscillations [10]. In primates, reduced vocalization and prolonged immobility may reflect transient parasympathetic dominance and autonomic withdrawal consistent with acute system wide coherence destabilization,

whereas in corvids, intensified and coordinated vocal bursts may function as acoustic entrainment signals that promote rapid realignment of group level temporal structure. Importantly, this framework does not posit residual electromagnetic emission from the deceased organism, nor does it invoke any non-physical persistence mechanism; rather, explanatory emphasis is placed on the living network and its response to what may be termed a *coherence void, the abrupt absence of a previously entrained rhythmic contributor within a dynamically coupled system*. The site of death thus becomes encoded not merely as a physical location but as a spatial marker of relational discontinuity within the group's field like interaction structure. Recurrent visitation can accordingly be interpreted as repeated engagement with the locus at which maximal phase collapse was first registered, *representing iterative attempts at network reorganization and stabilization following structural oscillator loss* [8]. Within the Heart-Based Resonant Field Theory (HBRF), grief related behaviors in social animals can be interpreted as emergent, system-level manifestations of distributed coherence destabilization rather than solely as affective or cognitive reactions localized within individual nervous systems. In this framework, socially bonded organisms participate in partially phase-coupled physiological networks mediated by rhythmic autonomic and cardiac oscillatory activity. Through repeated interaction, proximity, and affiliative engagement, these organisms develop statistically stable patterns of interindividual entrainment across heart rate variability, respiratory rhythms, and affect linked neurocardiac dynamics [4]. The social group thereby constitutes a metastable dynamical configuration in which each member functions as a coherence contributing node within a larger oscillatory assembly. At biological death, the critical event is not the emission of a novel signal, nor the persistence of residual electromagnetic activity from the deceased body, *but the abrupt cessation of an active macroscopic oscillator that had previously participated in maintaining network phase alignment. The surviving organisms are thus confronted with a sudden discontinuity in previously entrained rhythmic structure*. From a nonlinear dynamical systems perspective, removal of a coherence stabilizing node can induce transient phase drift, increased variability in autonomic indices, and reorganization of network attractor states. The behavioral repertoire observed, circling, gathering, vocal modulation, immobility, guarding, or recurrent visitation, may therefore represent embodied attempts at restoring stability within a perturbed oscillatory network. In this sense, mourning-like rituals can be conceptualized as network-level phase responses to coherence node removal. They reflect adaptive recalibration processes operating across distributed biological systems rather than anomalies of emotion alone. The organism does not orient toward a metaphysical continuation of the deceased; instead, it responds to the measurable absence of a formerly entrained rhythmic contributor within a socially coupled dynamical matrix. Grief behaviors thus become observable signatures of field-coupled biological systems undergoing structural reorganization after oscillator loss, macroscopic expressions of a living network striving to re-establish coherent integration following abrupt relational collapse [9] (**Figures 4(a)-(e)**).

4. From Emission to Absence: Reconstructing Mourning as Distributed Network Reorganization in the HBRF Framework

Within the Heart-Based Resonant Field (HBRF) framework, the biological heart is conceptualized not merely as a hemodynamic pump but as the organism's dominant macroscopic oscillator, an electromechanical structure generating the most powerful rhythmic electromagnetic field in the body. Through its cyclical depolarization-repolarization dynamics, the heart produces broadband electromagnetic fluctuations that propagate through conductive biological tissues and extend measurably beyond the body surface. These oscillations are not random; they exhibit structured variability (e.g., heart rate variability dynamics) reflecting integrated autonomic, limbic, and cortical regulation [11]. In HBRF terms, the cardiac field functions as a *coherence generator*, a large-scale integrative oscillator capable of stabilizing intra-organismic physiological networks and, under conditions of sustained proximity, contributing to weak inter-organismic phase coupling [4]. Social groups may therefore be modeled as assemblies of dynamically coupled bioelectromagnetic systems in which partial phase entrainment emerges through repeated interaction, shared affective states, and autonomic synchronization. Over time, bonded individuals develop statistically stable coherence relationships, forming distributed network attractor states that extend beyond isolated neural processing.

Biological death introduces a discontinuity of a fundamentally different order. At the moment of irreversible cardiac arrest very important physiological and energetic perturbances take place. the rhythmic electromechanical oscillation of the heart ceases, the structured electromagnetic field generated by coordinated myocardial depolarization collapses to background noise levels, autonomic variability signatures (HRV-based coherence patterns) terminate and the organism is no longer capable of participating as an active oscillatory node within the socially entrained network. Importantly, the electromagnetic field of a living organism is not a static residual property of tissue, it is a dynamically sustained phenomenon contingent upon ongoing metabolic and electrophysiological activity. When myocardial excitation ceases, field generation does not gradually fade in a functionally coherent manner but instead, it terminates as an organized oscillator. What remains is passive biological matter, no longer producing structured rhythmic output capable of entraining or stabilizing surrounding systems.

This creates a central explanatory constraint within the HBRF framework: mourning-like behaviors cannot plausibly be attributed to continued electromagnetic emission or active field signaling from the corpse. Such an assumption would contradict fundamental principles of electrophysiology and thermodynamic irreversibility. The deceased body, lacking sustained ionic flux and organized depolarization waves, cannot function as a coherence-emitting structure. Therefore, the theoretical locus of explanation must shift decisively from the deceased organism to

the surviving network. The critical event is not “field persistence,” but ***node removal***. In a system of weakly coupled nonlinear oscillators, the abrupt loss of a coherence generating element alters global phase relationships, increases entropy, and destabilizes previously maintained synchronization patterns. Under this formulation, the problem of mourning becomes a systems-level question: How does a distributed network of living oscillators reorganize when a previously entraining cardiac node is suddenly removed?

The behavioral manifestations observed in elephants, primates, and corvids are thus reframed not as responses to an emitted signal from the deceased, but as emergent properties of coherence disruption within the surviving group. The death event constitutes a phase discontinuity within an inter-individual resonance structure. The corpse is not an active source; it is the spatial marker of where a coherence stabilizing oscillator ceased to exist. Accordingly, HBRF shifts the explanatory focus from postmortem emission to the consequences of oscillator absence within the surviving network:

- From emission to absence
- From corpse-centered causation to network-centered dynamics
- From residual signal hypotheses to phase destabilization theory

5. Network Coherence Collapse Hypothesis

Social Organisms as Coupled Oscillatory Systems

Within our Heart-Based Resonant Field (HBRF) framework, social mammals are modeled not as isolated neurocognitive processors but as hierarchically organized, multi-scale oscillatory systems embedded within shared environmental and relational fields. Each organism contains nested rhythmic subsystems, cardiac, respiratory, vascular, neuroelectric, endocrine, operating across interacting temporal scales [12]. Among these, the cardiac oscillator occupies a privileged integrative position due to its continuous rhythmicity, high signal amplitude, and bidirectional coupling the organism central autonomic and limbic circuits as well as the space [13]. When individuals engage in sustained social interaction, through proximity, touch, vocal exchange, visual attunement, or coordinated movement, *weak coupling mechanisms allow partial phase alignment across physiological variables*. Empirical studies have demonstrated interindividual synchronization of heart-rate variability, respiratory activity, electrodermal signals, and neural oscillatory activity during social interaction. These observations establish the occurrence of physiological synchrony but do not, by themselves, identify the mechanism responsible for that synchrony. Established routes of interpersonal coupling include visual, auditory, tactile, behavioral, respiratory, and autonomic interactions. Within the HBRF framework, we additionally hypothesize that cardiac-generated electromagnetic fields may contribute to interindividual phase coupling. This proposed electromagnetic contribution has not yet been demonstrated as an independent causal mechanism and therefore remains a testable component of the HBRF/NCC frame-

work [14]. Thus, bonded social groups can be conceptualized as networks of **weakly coupled nonlinear oscillators** exhibiting metastable phase locking. Their stability is not static but dynamically maintained through continuous micro adjustments in autonomic tone and rhythmic entrainment. Repeated interaction strengthens statistical coherence across dyads and groups, leading to the emergence of higher order attractor states, distributed patterns of synchronized variability that reduce system entropy and enhance collective predictability. In this context, a dominant or deeply bonded individual may function as a **coherence stabilizing node** within the network. Such an individual, by virtue of social centrality, affective salience, or physiological robustness, may contribute more strongly to the maintenance of group-level phase alignment than less connected members. *The removal of this node through biological death therefore constitutes more than a social absence; it represents a structural perturbation to the network's oscillatory architecture.* From nonlinear dynamical systems theory, abrupt node removal in a partially synchronized oscillator network can produce several predictable consequences:

- **Phase Drift:** Previously entrained oscillators lose a shared temporal reference, resulting in gradual desynchronization and widening phase dispersion.
- **Entropy Increase:** Loss of coherence reduces global order, increasing variability and decreasing predictability across network dynamics.
- **Oscillatory Instability:** Perturbations may amplify through feedback loops, generating transient fluctuations in autonomic balance and behavioral regulation.
- **Attractor Reconfiguration:** The system may transition to a new metastable state as surviving oscillators reorganize around a revised coherence structure.

These processes are not abstract mathematical curiosities; they have physiological correlates. Phase drift may manifest as dysregulated HRV patterns among surviving group members. Entropy increase may correspond to heightened stress biomarkers or irregular movement patterns. Oscillatory instability may appear as agitation, freezing, or repetitive motor acts. Attractor reconfiguration may involve gradual restoration of synchrony through new dominance hierarchies or social bonds. Under this model, mourning-like behaviors are interpreted as behavioral level expressions of network re-stabilization dynamics. Physical readapted behaviors might be explained as follows:

- **Circling behaviors** (observed in elephants and corvids) can be understood as spatially mediated coherence search processes. Movement around the locus of node loss may increase sensory coupling among surviving members, enhancing opportunities for re-entrainment through proximity based feedback.
- **Vocalization bursts** may serve as acoustic entrainment signals, externally broadcast rhythmic patterns capable of re-synchronizing dispersed oscillators via auditory-limbic-autonomic pathways.
- **Proximity maintenance or collective stillness** may facilitate parasympathetic co-regulation, allowing gradual phase realignment through shared autonomic quieting.

Crucially, these behaviors do not imply detection of an active post-mortem field. Rather, they represent adaptive responses *to coherence discontinuity*, the abrupt disappearance of a rhythmic contributor that previously participated in maintaining network stability. *Collectively, these processes define Network Coherence Collapse: transient destabilization of a previously coordinated social biological network following loss of an integrated oscillatory node, followed by progressive reorganization toward a new metastable state.*

6. Coherence Void Detection through the Alabdulgader HBRF Theory Lens

Building directly on the Network Coherence Collapse hypothesis described in Section 5, Section 6 addresses how the surviving network may register the abrupt absence of a previously entrained oscillatory contributor. This process is termed Coherence Void Detection. The explanatory emphasis therefore shifts from signal detection to absence detection, from emission based causation to discontinuity based perturbation. In socially bonded mammals, repeated interaction fosters partial phase alignment across cardiac, respiratory, and autonomic rhythms. These entrainment relationships are not merely symbolic; they are embodied through measurable synchronization in heart rate variability (HRV), baroreflex modulation, and affect-linked neurocardiac oscillations. Over time, such synchronization establishes a distributed relational baseline, a statistically stable pattern of inter individual temporal predictability. When one member of the network dies, three simultaneous disruptions occur: the sudden termination of previously entrained cardiac oscillatory input, the collapse of dynamic bioelectromagnetic coupling between that individual and surrounding conspecifics, and the destabilization of collective autonomic synchronization patterns previously supported by the deceased oscillator [15]. From a systems perspective, the surviving organisms are not detecting a residual field; they are encountering a predictive failure within an established oscillatory matrix. Biological systems are highly sensitive to violations of expected rhythmic contingencies. Just as neural circuits detect missing beats in auditory sequences or disrupted circadian regularity, socially coupled autonomic systems may detect the sudden loss of a recurrent rhythmic contributor. This detection is not conscious inference but dynamical perturbation: A previously present coherence source is no longer participating in phase alignment. The resulting state may be termed Coherence Void Phenomenology, a systems level condition characterized by the perception (at physiological levels) of rhythmic absence within a previously synchronized network. It is analogous to the sudden silence in a tightly synchronized ensemble: the absence itself becomes the salient event. Importantly, coherence void detection does not require exotic mechanisms [16]. It arises naturally in networks of weakly coupled nonlinear oscillators. *When one oscillator abruptly ceases: phase relationships recalibrate, variance increases, cross correlation metrics decay and network entropy rises.* The system experiences a transient instability as it searches for a new attractor configuration. This instability may manifest behaviorally as vigilance, aggregation, immobility, or repetitive move-

ment. Within this framework, the grave site assumes a functional role not because it emits a signal, but because it marks the spatial coordinates at which network phase collapse. It becomes: a spatial memory anchor, The location where maximal entrainment breakdown occurred, encoded through limbic hippocampal circuits and autonomic imprinting, a locus of relational discontinuity: The physical point associated with abrupt oscillator extinction within the social matrix, and network phase collapse node: the environmental reference point around which coherence destabilization initially propagated. *Recurrent visitation to this site can therefore be interpreted as iterative exposure to a relational discontinuity rather than communication with a deceased entity.* The behavior is directed toward the unresolved perturbation in the living network's coherence structure. From an our HBRF standpoint, organisms are not responding to a corpse as an active emitter. They are responding to *the absence of structured oscillatory participation* in a previously entrained system. *The corpse is inert; the network is destabilized.* Thus, mourning associated behaviors: circling, gathering, guarding, and silence are best understood as adaptive attempts to process and reorganize around a coherence void. The surviving oscillators increase proximity, modulate vocal rhythms, or maintain spatial fixation in ways that may facilitate gradual phase realignment and entropy reduction. In summary, Coherence Void Detection represents a dynamical systems phenomenon: the biological registration of abrupt oscillator extinction within a socially coupled resonance network. The behavioral focus is not the deceased organism itself, but the discontinuity in relational coherence that death imposes upon the living system [17]. Within the Heart-Based Resonant Field (HBRF) framework, post-mortem aggregation, circling, guarding, and collective vocalization are interpreted not as symbolic gestures alone, but as **emergent regulatory operations** undertaken by a destabilized oscillator network attempting to restore coherence after node extinction. When a coherence-generating cardiac oscillator is abruptly removed from a socially entrained system, the surviving organisms experience increased phase dispersion, elevated entropy, and reduced cross-correlation among autonomic rhythms. The network must either reorganize or remain in a prolonged destabilized state. Behavioral synchronization during mourning can therefore be modeled as a **re-stabilization protocol** operating across spatial, autonomic, and dynamical scales [18].

7. Cardiac Field Reorganization after Node Extinction: Spatial and Autonomic Re-Coupling in the HBRF Framework

7.1. Mourning as Cardiac Field Reorganization: Spatial and Autonomic Recoupling after Coherence Collapse in the HBRF Framework

Following network coherence collapse and coherence void detection, the next predicted stage is spatial and autonomic recoupling among surviving organisms. This section therefore focuses on mechanisms of re-stabilization rather than reintroducing the preceding collapse process. Circling, clustering, guarding, and prox-

imity maintenance function as spatial recoupling mechanisms. In dynamical systems theory, synchronization stability depends critically on coupling strength. When oscillators drift out of phase following perturbation, increasing interaction density can restore partial phase locking. Social mammals achieve this biologically by reducing spatial separation and increasing multimodal overlap, visual entrainment, tactile contact, acoustic exchange, and shared environmental feedback. Physical contact (trunk touching in elephants, grooming in primates, body leaning in corvids), spatial compression of group geometry, and coordinated orientation toward a shared focal point effectively increase interaction bandwidth among remaining nodes. From an HBRF perspective, this amplifies coupling coefficients within the cardiac field network, enhancing the probability of realignment among surviving oscillators. Spatial convergence is therefore not incidental; it is a structural maneuver that increases the likelihood of phase stabilization after coherence collapse. A second layer of re-stabilization operates through autonomic coregulation. The autonomic nervous system is intrinsically oscillatory, and heart rate variability (HRV) dynamics are highly sensitive to social context. In bonded dyads and cohesive groups, partial synchronization of HRV, respiratory rhythms, and affect linked autonomic fluctuations has been empirically demonstrated across mammals [19]. Removal of a coherence stabilizing individual may produce transient sympathetic dominance, irregular variability spectra, and heightened physiological dispersion among survivors. Behavioral stillness, collective quietude, synchronized vocalizations, or slow coordinated movement may function to shift group autonomic tone toward parasympathetic stabilization. Prolonged silent standing can facilitate vagal convergence; rhythmic vocal bursts may provide acoustic scaffolding capable of re-entraining cardiac oscillations through auditory-limbic pathways; repetitive circling at uniform speeds may generate locomotor-respiratory coupling that stabilizes variability patterns. These behaviors reduce physiological entropy and enhance predictability within the surviving network. Under HBRF, such actions are physiologically and biophysical distributed field regulation strategies: the remaining oscillators modulate themselves and one another to regain partial synchrony within the shared bioelectromagnetic matrix.

7.2. Attractor Reconfiguration and Network Topology Shift toward Metastable Equilibrium

Within the Heart-Based Resonant Field (HBRF) framework, mourning behaviors extend beyond immediate resynchronization and participate in longer term attractor restructuring within a socially coupled cardiac oscillator network. In complex dynamical systems, removal of a central node redistributes regulatory influence across remaining elements, forcing recalibration of interaction strengths, phase relationships, and coupling topology. Analogously, following the loss of a coherence generating individual, dominance hierarchies, affiliative bonds, and interaction frequencies among surviving organisms gradually reorganize. Cross cor-

relation matrices linking cardiac and respiratory oscillators shift over time toward a new metastable equilibrium. The system does not revert to its prior attractor; rather, it transitions toward a newly configured coherence topology reflecting altered network architecture. From an HBRF standpoint, this transition corresponds to measurable biophysical adjustments: phase alignment metrics among cardiac oscillators recalibrate, variability spectra reorganize across frequency bands, and group level entropy declines as synchronization re-emerges. The ritualized and repetitive qualities often observed in mourning like behaviors, circling, prolonged proximity, synchronized stillness, coordinated vocalization, can be interpreted as iterative sampling of network configurations. These behaviors function as biological search processes exploring phase space until a lower energy, dynamically stable configuration is achieved. *In systems terms, mourning represents a controlled passage through transient instability toward a revised attractor basin.* Established findings in interpersonal and comparative physiology provide convergent support for this interpretation. Across mammals, heart rate entrainment, respiratory coupling, and shared autonomic variability emerge during emotional bonding and cooperative engagement. Collective stress exposure produces measurable coherence decay followed by coordinated recovery, while synchronized vocalization and coordinated movement induce convergence of cardiac and respiratory rhythms among participants [20]. These phenomena demonstrate that social organisms operate as partially coupled oscillator networks capable of both destabilization and re-synchronization. HBRF extends this principle by positioning the cardiac oscillator as a central coherence generating element within a distributed bioelectromagnetic field [4]. When one node ceases oscillatory participation, the perturbation propagates across the shared resonant matrix, manifesting as behavioral convergence and autonomic adjustment among survivors. Aggregation, circling, silence, vocalization, and spatial compression are thus emergent regulatory operations designed to increase coupling strength, reduce physiological entropy through autonomic coregulation, and facilitate transition toward a new stable attractor state. In this view, grief is not solely an emotional construct but a dynamical systems transition, an intermediate instability between two coherent states of a socially coupled cardiac field network. *The network does not merely mourn; it re-organizes.*

8. Methodological Delimitation: Empirical Boundaries and Biophysical Grounding

The Heart-Based Resonant Field (HBRF) framework is explicitly constrained by established electrophysiology, nonlinear dynamical systems theory, and classical electromagnetic principles. It does not posit metaphysical continuity, extracorporeal agency, or anomalous energy persistence, but is restricted to mechanisms that are measurable, mathematically describable, and compatible with conservation laws and thermodynamic irreversibility. At biological death, coordinated myocar-

dial depolarization ceases irreversibly as ionic gradients dissipate, ATP-dependent membrane pumps fail, and organized action potential propagation collapses. Because electromagnetic field generation in excitable tissue is strictly derivative of synchronized ionic flux, the cessation of structured depolarization-repolarization cycles entails termination of coherent, phase stable cardiac field emission. Any residual fluctuations decay rapidly to stochastic background noise governed by passive conductive and thermal processes. No known electrophysiological mechanism permits persistence of organized oscillatory emission after irreversible cardiac arrest [21]. Within this biophysical boundary, social organisms are modeled as networks of weakly coupled nonlinear oscillators, a formalism widely used in complex systems science and articulated in network theory by investigators such as Stefano Boccaletti. In such systems, removal of a highly connected node predictably induces transient desynchronization, redistribution of coupling weights, phase drift, entropy increase, and eventual attractor reconfiguration. These dynamics are well characterized in neural lesion models, ecological collapse, infrastructural grid failure, and social network fragmentation, and require no appeal to external agency. HBRF framework interprets mourning like behaviors as macroscopic biological correlates of this intrinsic topological perturbation: *the destabilization reflects endogenous network reorganization among surviving organisms rather than communication with a deceased emitter* [22]. Cardiac rhythms are measurably coupled to central autonomic and limbic networks, and empirical research in social neurocardiology has documented interindividual synchronization of heart rate variability and autonomic co-regulation during stable social interaction. Abrupt loss of a socially entrained individual therefore constitutes a regulatory perturbation within an already coupled system. The ensuing autonomic dysregulation, altered HRV structure, vigilance, aggregation, and vocal modulation are interpreted as endogenous recalibration processes within living neurocardiac networks. Resilience theory further predicts that complex adaptive systems undergoing node removal exhibit transient variability increases and progressive reorganization toward a new metastable configuration. In this view, collective gathering, reduced mobility, and coordinated behaviors function as mechanisms that enhance intra group coupling and facilitate restabilization of the modified topology [9]. Accordingly, HBRF establishes a strict epistemological boundary: mourning behaviors are framed as measurable signatures of distributed dynamical reorganization following irreversible oscillator removal, fully consistent with electrophysiological cessation of field generation, entropy increase at death, and established nonlinear systems dynamics. The framework advances a biophysically constrained and empirically falsifiable systems model rather than a continuity hypothesis.

To ensure conceptual precision and empirical falsifiability, the principal dynamical terms used throughout the NCC/BST-GC framework are operationally defined below. These definitions specify how each construct may be quantified experimentally or computationally and distinguish formal dynamical variables from broader descriptive usage (**Table 1**).

Table 1. Operational definitions and quantitative measures of core NCC/BST-GC dynamical constructs.

Term	Operational definition in the present framework	Quantification/empirical indicator
Coherence	A state of stable, ordered and self-sustained oscillatory synchronization across physiological or neural systems, allowing predictable phase and amplitude relationships over time.	Magnitude-squared coherence (MSC), phase-locking value (PLV), coherence index of HRV, EEG/MEG coherence (0-1) or z-score relative to baseline.
Phase synchronization	A consistent temporal alignment (phase relationship) between two or more oscillatory signals, regardless of amplitude similarity.	Phase-locking value (PLV), phase synchronization index (PSI), mean phase difference (radians or degrees), or circular statistics (e.g., Rayleigh test).
Coupling strength	The magnitude of functional interaction or influence between two oscillatory systems (e.g., heart-brain, heart-respiration), reflected in the degree to which the activity of one system predicts or modulates the other.	Cross-correlation coefficient, transfer entropy, Granger causality, directed coherence, or coupling index (dimensionless units, 0-1 or standardized effect size).
Entropy	A measure of signal complexity or unpredictability. In this framework, higher entropy reflects more irregular and less organized physiological or network dynamics, while lower entropy reflects greater order and coherence.	Sample entropy (SampEn), multiscale entropy (MSE), permutation entropy, or spectral entropy (dimensionless units).
Attractor state	A relatively stable pattern of system dynamics toward which the network tends to evolve. In physiological terms, an attractor state represents a recurrent, stable configuration of coordinated oscillatory activity (e.g., coherent, incoherent, or transitional states).	State-space analysis, recurrence plots, attractor basin analysis, dynamical systems modeling, or metastability metrics (e.g., dwell time, state probability).
Network centrality	A measure of the relative importance or influence of a node (e.g., individual, brain region, or physiological system) within a larger network, based on its connectivity pattern.	Degree centrality, betweenness centrality, eigenvector centrality, closeness centrality, or network hub score (dimensionless units, often normalized 0-1 or z-score).

On the other hand, it is worth stressing on confounds and alternative mechanisms. Established mechanisms, including generalized stress responses, shared visual and auditory cues, olfactory information, social learning, disruption of established routines, changes in dominance or affiliative structure, and common environmental inputs, may independently or jointly produce changes in behavior and physiological synchronization following the loss of a group member. Future experimental designs must separate these influences through appropriate controls, including matched non lethal stress conditions, manipulation of sensory access, assessment of social network changes, and measurement of shared environmental variables.

9. Quantitative, Testable Predictions and Falsifiability Framework

To ensure empirical rigor and clear falsifiability, the Network Coherence Collapse hypothesis within the Heart-Based Resonant Field (HBRF) framework generates explicit quantitative predictions regarding physiological synchronization, entropy dynamics, spatial topology, and electromagnetic constraints following irreversible oscillator removal. If bonded social groups function as weakly coupled nonlinear oscillator networks, then the death of a socially central individual should produce measurable and time locked destabilization within the surviving network. Specifically, interindividual heart rate variability (HRV) synchronization, quantified through phase-locking value, cross-correlation coefficients, and coherence spectra, is predicted to decrease following the confirmed death of a socially integrated group member relative to the pre-loss baseline. The magnitude and temporal profile of this desynchronization are expected to vary according to species, group structure, strength of pre-existing social bonds, environmental conditions, and the network centrality of the lost individual. At this stage, no fixed percentage reduction or predefined post-loss temporal window is assumed. Initial prospective studies should therefore establish baseline variability, effect-size distributions, and the temporal evolution of post-loss synchronization changes, allowing empirically derived thresholds and time windows to be specified and preregistered in subsequent confirmatory studies [20]. This desynchronization should be accompanied by increased phase dispersion and elevated multiscale entropy across group-level autonomic signals, reflecting transient entropy amplification consistent with nonlinear node removal dynamics described in complex systems theory, including the work of Steven H. Strogatz and Stefano Boccaletti [20] [23]. The magnitude of destabilization is predicted to scale with the deceased individual's pre-loss network centrality, such that degree, betweenness, or eigenvector centrality metrics computed from baseline synchronization networks positively correlate with the magnitude of post-loss coherence decay. A statistically meaningful correlation (e.g., $r \geq 0.5$) would support topology-dependent vulnerability, whereas absence of such association would weaken the hypothesis. At the behavioral level, acute destabilization is expected to coincide with measurable spatial compression of the surviving group, operationalized as reduced mean interindividual distance and increased clustering coefficients, reflecting compensatory strengthening of coupling density. Coordinated stillness, circling, or vocal synchronization should correspond to increased movement phase locking or spectral convergence, indicating re-entrainment processes rather than random agitation. Longitudinally, the network should not revert instantaneously to its prior attractor configuration but instead transition through a metastable reorganization phase analogous to metastable dynamics described in neural systems research. Global coherence metrics are expected to partially recover over weeks while exhibiting persistent alterations in connectivity topology, reflecting attractor reconfiguration rather than simple restoration. Importantly, the framework makes a strict negative prediction grounded

in electrophysiology and Maxwellian field constraints: organized electromagnetic field emission from the deceased organism should cease immediately following irreversible cardiac arrest, with magnetocardiographic amplitude decaying to stochastic baseline noise. Detection of sustained phase stable oscillatory emission post mortem would directly falsify the biophysical premises of the model [9] [20].

Computationally, removal of a high centrality node in simulated Kuramoto-type oscillator networks should reproduce transient phase dispersion and entropy elevation consistent with biological observations. Failure of biologically plausible coupling models to generate destabilization following node removal would undermine the dynamical systems foundation of the theory. Critically, the predicted desynchronization pattern must be distinguishable from generalized stress responses; death related node removal should produce greater inter individual coherence decay and network topology shift than non-lethal stressors of comparable intensity. If no measurable pre-loss synchronization exists, if node removal fails to produce quantifiable desynchronization, if destabilization magnitude is unrelated to network centrality, if entropy does not increase, or if corpse-based organized electromagnetic emission persists, the Network Coherence Collapse hypothesis would be empirically weakened or rejected.

By specifying measurable variables, predicted effect sizes, temporal windows, scaling relationships, and clear disconfirmation criteria, the HBRF framework positions mourning-like behaviors as experimentally tractable manifestations of distributed oscillator reorganization within living systems rather than metaphorical constructs. The model therefore stands or falls on quantifiable synchronization dynamics, entropy shifts, and topology dependent recovery trajectories.

10. Biological Spectrum Theory of Grief Coherence (BST-GC): A Multiscale Systems Framework for Mourning Dynamics in Socially Complex Vertebrates

The theoretical developments and conceptual synthesis presented in this manuscript support a broader framework extending beyond immediate post-loss synchronization dynamics. To organize the Network Coherence Collapse hypothesis (which is based on the broad principles of the HBRF Theory) within a unified biological architecture, *we propose the Biological Spectrum Theory of Grief Coherence (BST-GC)*. BST-GC is introduced as a systems level extension that positions mourning not as an isolated emotional event, but as a measurable process of coherence redistribution occurring across nested levels of biological organization following irreversible removal of a socially integrated organism. The framework emerges directly from the preceding sections of this manuscript. If mourning reflects transient coherence collapse after extinction of a socially central oscillator, if surviving organisms exhibit measurable autonomic destabilization and behavioral recoupling, and if recovery follows predictable attractor reorganization dynamics, then these processes may represent manifestations of a more general biological principle operating across multiple scales. BST-GC proposes that living

systems maintain functional stability through continuous coordination across a spectrum of interacting coherence domains rather than through isolated organ control. Within this formulation, coherence is defined as the temporary emergence of organized biological order among partially coupled oscillatory processes operating across cellular, physiological, behavioral, and social levels. Accordingly, grief represents temporary disruption of this distributed organization. The proposed biological spectrum contains five interconnected domains.

Level I: Cellular Coherence

The most fundamental layer consists of intracellular and intercellular coordination processes including membrane excitability, ionic fluxes, mitochondrial rhythmicity, intracellular signaling pathways, metabolic oscillations, and electrophysiological organization. At this level, biological identity emerges from local synchronization rather than static structure. Loss of systemic stability produces altered signaling regularity, redistribution of energetic demand, and increased local entropy [4].

Level II: Physiological Organ Coherence

Cellular organization becomes integrated into organ-scale oscillatory systems. Cardiovascular, respiratory, endocrine, and autonomic rhythms generate dynamic regulatory fields that maintain physiological predictability. Within this manuscript's framework, cardiac rhythmic organization occupies particular importance because of its continuous temporal output, central autonomic coupling, and known participation in organism-wide synchronization [24]. Loss of coherence at this level manifests as altered variability spectra, autonomic imbalance, reduced adaptive responsiveness, and increased physiological noise.

Level III: Organismal Coherence

At the whole-organism scale, coherent function emerges through integration among neural processing, cardiac signaling, autonomic regulation, endocrine adaptation, sensory interpretation, memory, movement, and behavioral control. Organismal identity is therefore interpreted as a metastable biological state continuously reconstructed through coordinated oscillatory interaction. This view aligns with the present manuscript's interpretation that behavioral responses following loss are not isolated reactions but indicators of distributed regulatory disturbance [4].

Level IV: Social Coherence

Beyond the individual organism, coherence extends into bonded biological networks. Social mammals exhibit measurable synchronization across movement, vigilance, autonomic activity, respiratory dynamics, affective expression, and cooperative behavior. The death of a socially integrated member therefore produces more than emotional loss. It removes a regulatory node embedded within a distributed coherence structure. The behavioral phenomena reviewed throughout this manuscript, circling, aggregation, silence, guarding, coordinated stillness, proximity maintenance, and vocal modulation, are interpreted within BST-GC as emergent regulatory responses attempting to reduce entropy and restore synchro-

nization among surviving nodes. These actions increase interaction density and enhance the probability of partial re-entrainment.

Level V: Ecological Coherence

The broadest layer considers the organism as embedded within larger environmental temporal structures. Circadian timing, seasonal periodicities, environmental rhythms, and geophysical variability provide persistent background constraints to which biological systems adapt [24]. BST-GC does not require direct environmental determination of behavior but recognizes that living systems operate within structured temporal environments that influence adaptive organization. Importantly, coherence across levels is not permanently fixed. Biological systems continuously transition between states of stronger and weaker integration. Under normal conditions, these transitions remain bounded. Death, however, introduces abrupt coherence discontinuity. *Within BST-GC, the deceased organism contributes no continued organized oscillatory activity following irreversible physiological cessation. Instead, mourning originates from destabilization among surviving biological units. The system temporarily loses prior attractor stability. Phase dispersion increases. Entropy rises. Behavior becomes exploratory. Spatial organization compresses. Autonomic variability shifts.* Repeated social interactions function as iterative biological sampling processes through which surviving organisms discover a revised coherent configuration. *Accordingly, mourning is interpreted not as breakdown of order but as active reconstruction of order.* This interpretation provides conceptual continuity with the Network Coherence Collapse hypothesis developed in earlier sections. The coherence collapse model describes the immediate perturbation. BST-GC describes the broader architecture within which such perturbations become biologically meaningful. Importantly, the framework remains constrained by the empirical boundaries established in Section 8 and the falsifiability criteria defined in Section 9. No postmortem persistence, external agency, or violation of electrophysiological constraints is proposed. The theory stands only insofar as measurable changes in synchronization, entropy, coupling topology, and recovery trajectories can be demonstrated. Future work may evaluate BST-GC through longitudinal heart-rate variability studies, multilayer synchronization analysis, entropy mapping, behavioral phase coupling, cross species comparisons, and computational modeling of coherence redistribution following node extinction. From this perspective, grief becomes neither metaphor nor anomaly. It becomes one of biology's most sophisticated mechanisms for restoring organization after irreversible loss (See **Figure 5**).

11. Conclusions

This manuscript proposes that mourning-like behaviors observed across mammalian and social biological systems may be interpreted through a new systems-level framework centered on coherence, synchronization, and adaptive reorganization rather than exclusively through emotional, symbolic, or anthropomorphic

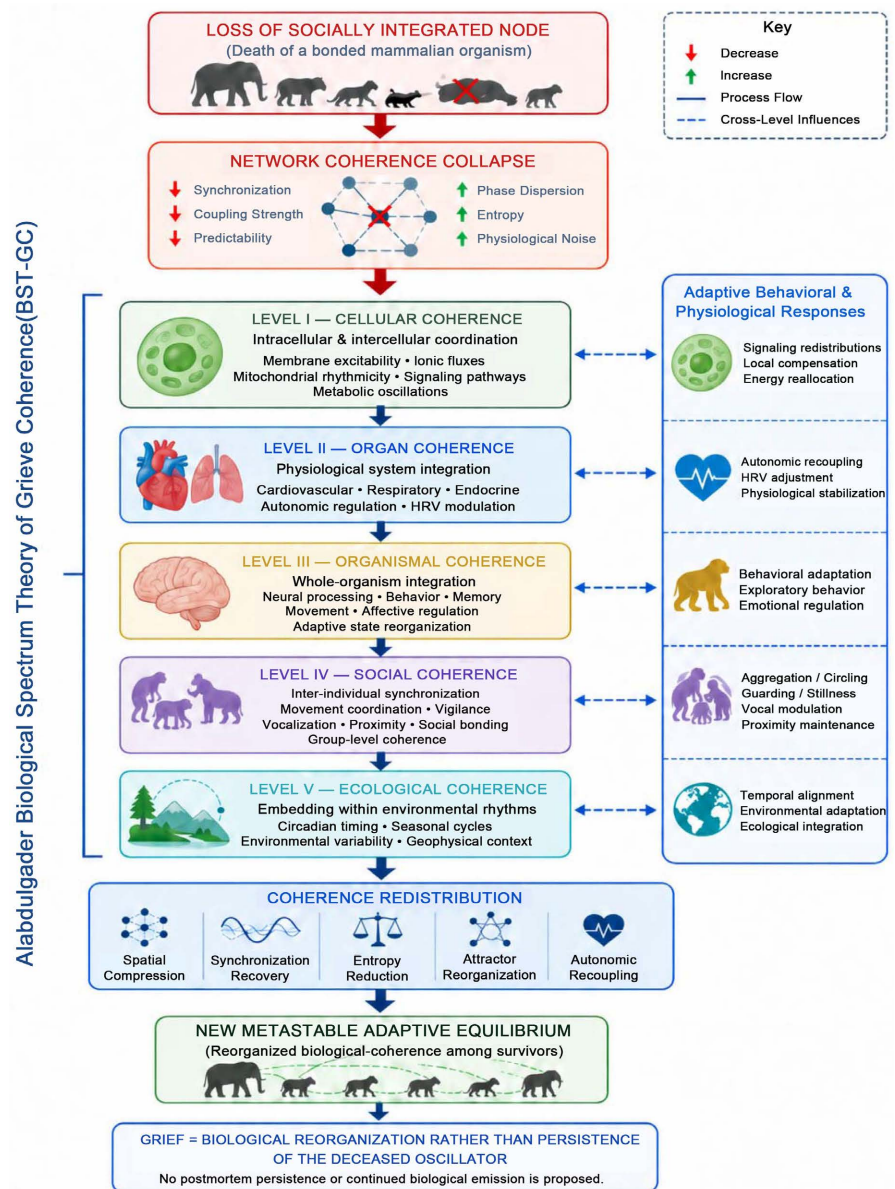


Figure 5. Biological spectrum theory of grief coherence (BST-GC). Multiscale schematic of biological reorganization following the loss of a socially integrated organism. Node loss is proposed to initiate network coherence collapse, with reduced synchronization, coupling strength, and predictability alongside increased phase dispersion, entropy, and physiological noise. Reorganization is distributed across five interacting levels, cellular, organ, organismal, social, and ecological coherence, with corresponding adaptive behavioral and physiological responses. Coherence redistribution through spatial compression, synchronization recovery, entropy reduction, attractor reorganization, and autonomic recoupling is proposed to culminate in a new metastable adaptive equilibrium. The model explicitly concerns reorganization among surviving systems and denying postmortem persistence or continued biological emission from the deceased oscillator.

explanations. Building upon the Heart-Based Resonant Field (HBRF) framework, the Network Coherence Collapse hypothesis introduced here interprets biological death not as the emergence of a postmortem signal, but as the abrupt extinction

of a previously integrated oscillatory contributor within a socially coupled living network. The primary event is therefore not continued activity from the deceased organism, but structured biological absence: disruption of established rhythmic participation within an already coordinated physiological architecture. Within this interpretation, behaviors commonly observed after loss, including gathering, circling, guarding, stillness, vocal modulation, and prolonged proximity, are viewed as emergent regulatory responses occurring among surviving organisms. These responses are proposed to function as coherence restoration processes operating across spatial, autonomic, behavioral, and physiological domains. Mourning is therefore reframed as an active biological transition through which distributed living systems reduce entropy, strengthen residual coupling, and reorganize toward a revised metastable state.

The Biological Spectrum Theory of Grief Coherence (BST-GC) extends this interpretation beyond immediate network destabilization by proposing that grief reflects temporary redistribution of coherence across nested biological scales extending from cellular regulation to physiological integration, organismal adaptation, social synchronization, and ecological embedding. Under this formulation, coherence becomes not a static property but a dynamic organizational principle through which living systems preserve functional continuity under conditions of irreversible change. Importantly, this framework remains explicitly bounded by established electrophysiology, nonlinear systems theory, and thermodynamic constraints. No postmortem persistence, external agency, or continuation of organized biological emission is proposed. The model stands only insofar as measurable predictions concerning synchronization, entropy, coupling topology, autonomic regulation, and recovery dynamics can be experimentally demonstrated and independently replicated. Accordingly, the contribution of this manuscript is not to explain death itself. Its contribution is to propose that grief may represent one of biology's most advanced adaptive operations: a multiscale process through which living systems detect discontinuity, redistribute organization, and reconstruct coherence after irreversible loss. If supported empirically, this perspective may provide a unifying conceptual language linking comparative thanatology, systems biology, social physiology, developmental organization, neurocardiology, and the broader study of how living systems preserve order in the face of disappearance. In this view, organisms do not merely endure loss. They reorganize around it.

12. Future Research Directions and Translational Perspectives

The Biological Spectrum Theory of Grief Coherence (BST-GC) proposed in this manuscript extends the study of mourning from descriptive behavioral observation toward a quantitative systems-biology framework centered on multiscale coherence dynamics. While the present work remains conceptual and hypothesis generating, it establishes a structured foundation from which future empirical

programs may emerge. **A first** priority is direct physiological validation. Longitudinal studies should evaluate whether the death of a socially integrated mammalian individual produces measurable disruption in group-level physiological organization. Simultaneous acquisition of heart-rate variability, respiratory entrainment, locomotor coordination, vocal synchronization, endocrine markers, and social proximity metrics before and after loss events may determine whether coherence redistribution follows reproducible trajectories across species. **Second**, future work should investigate whether mourning exhibits identifiable temporal phases. BST-GC predicts that biological grief is not instantaneous adaptation but a staged progression beginning with acute coherence disruption, followed by exploratory recoupling behavior, transient attractor instability, and eventual emergence of a revised metastable state. Time-series analysis and multiscale entropy approaches may allow quantification of these transitions.

Third, computational modeling should become a central methodological component. Network simulations incorporating node centrality, oscillator coupling strength, adaptive weighting, and entropy evolution may determine whether the observed behavioral phenomena of circling, aggregation, silence, guarding, and coordinated movement naturally emerge following irreversible node extinction. Comparison between simulated and biological systems may provide objective evaluation of the theory's explanatory power.

Fourth, comparative mammalian research should determine whether coherence redistribution obeys conserved biological principles. Large-brained social mammals, including elephants, cetaceans, primates, canids, and selected avian social systems, may provide opportunities to examine whether similar topological signatures of post-loss adaptation appear despite different neurobiological architectures.

Fifth, future investigations should examine developmental and evolutionary implications. If biological coherence operates across nested scales as proposed by BST-GC, then developmental resilience, attachment formation, social buffering, and adaptive recovery may represent manifestations of a common organizational principle rather than isolated phenomena. Understanding how coherence is formed, disrupted, and restored could therefore contribute to broader questions in social neurobiology, developmental physiology, and collective adaptation. An additional future direction concerns developmental biophysics and environmental modulation of biological organization. Recent work from our group reported geographic variation in congenital aortic valve stenosis incidence across regions of differing magnetic latitude and proposed a hypothesis-generating framework in which geophysical variables may deserve consideration as one component among broader developmental influences acting during cardiogenesis. While the mechanisms remain to be experimentally established, the proposed interaction with endothelial-mesenchymal transformation (EndoMT) signaling pathways highlights a possible bridge between environmental biology, developmental regulation, and systems-level coherence. Future studies may therefore examine whether princi-

ples of biological synchronization and multiscale organization extend beyond postnatal adaptive processes to include developmental windows during embryogenesis, using rigorous molecular, epidemiological, and mechanistic approaches [25].

Sixth, integration with environmental biology may offer additional explanatory depth. Because living systems operate within structured temporal environments, future studies may evaluate whether circadian organization, seasonal variation, and geophysical environmental factors influence the magnitude or duration of coherence reorganization after loss. Such studies would remain strictly constrained to measurable biological variables and should not imply external agency or persistence beyond established electrophysiological limits.

Finally, translation to human science represents an important future horizon. The framework presented here may eventually contribute to objective investigation of bereavement physiology, social resilience, autonomic recovery, and collective adaptation following loss in biology including human species. Quantifiable measures of synchronization, entropy regulation, and network restructuring may offer a new language connecting comparative thanatology, social neurocardiology, systems biology, and behavioral medicine. The long term value of BST-GC will not depend on conceptual novelty alone. Its value will depend on whether future evidence demonstrates that grief leaves measurable signatures of biological reorganization across scales, and whether those signatures reveal that mourning is not merely an emotional response to loss, but one of the most sophisticated adaptive mechanisms through which living systems preserve coherence after irreversible change.

Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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