

Geometry-Admissible Foundations of Biological Systems for Neurodegeneration in Alzheimer's Disease and Related Dementias

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Neurodegeneration is not a single observed signal; Bansal Neuron Modeling uses eleven geometry-admissible pillars to organize layered biological disruption into evidence-gated, review-only projections.

INTRODUCTION

Alzheimer's disease and related dementias involve progressive disruption of biological organization across molecular, cellular, neuronal, vascular, structural, and functional levels. Observable readouts such as MRI-derived atrophy, PET signal, CSF or plasma biomarkers, cognitive scores, voltage traces, spike trains, calcium signals, and field outputs represent projections of a deeper biological state rather than the complete biological system. Neuronal activity is commonly represented through observable signals such as membrane potential, spike trains, calcium readouts, phase trajectories, and field projections. However, these readouts do not represent the complete biological state of the neuron. A neuron also includes hidden electrophysiological, molecular, structural, transport, thermal, wave, synaptic, and evidence-gated biological layers. In Bansal Neuron Model, neuron is represented as a stratified hidden-state system rather than a single vector or single complex-number model.

METHODS

Proposed Novel B-Bio Theory, Frameworks and Pillars on SaMD- BVIDAL Clinical Software Suite

Bansal Neuron Modelling frames neurodegeneration as disruption of layered biological organization rather than a single diagnostic marker. The eleven Bansal pillars provide a structured foundation for representing hidden biological-state layers, geometry-admissible state spaces, projected observables, temporal trajectories, disease curvature, biological operators, path-dependent memory, entropy and stability change, fiber-bundle organization, multidirectional interactions, and state-to-state connection structure.

Eleven Bansal Pillars in Neurodegeneration Modelling

Algebra: Organizes biological disruption into stratified hidden-state layers such as scalar biomarkers, rhythms, morphology, transient change, transport, pulse-wave behavior, and local signalling.

Manifold: Places biological states on a geometry-admissible state space so that normal, vulnerable, and disrupted states can be represented as structured regions rather than isolated measurements.

Projection: Maps the hidden biological state into observable outputs such as MRI features, PET signal, CSF/plasma biomarkers, neuronal readouts, cognitive scores, and review-only summaries.

Trajectory: Represents neurodegeneration as an evolving biological path over time, including progression, compensation, instability, and transition from local deviation to broader system disruption.

Curvature: Describes disease burden as distortion or bending of the biological state geometry, helping represent deviation from admissible organization.

Operators: Represents biological process agents such as ion-channel activity, synaptic change, transport mechanisms, inflammation, vascular exchange, and biomarker perturbation.

Holonomy: Captures path-dependent biological memory, where the current state depends not only on present biomarkers but also on the route taken through prior biological changes.

Entropy: Represents loss of physiological order, increasing instability, uncertainty, or dispersion of the biological state during neurodegenerative progression.

Fiber Bundle: Connects local biological layers to global system structure, allowing molecular, cellular, neuronal, vascular, and clinical layers to remain linked without collapsing into one flat vector.

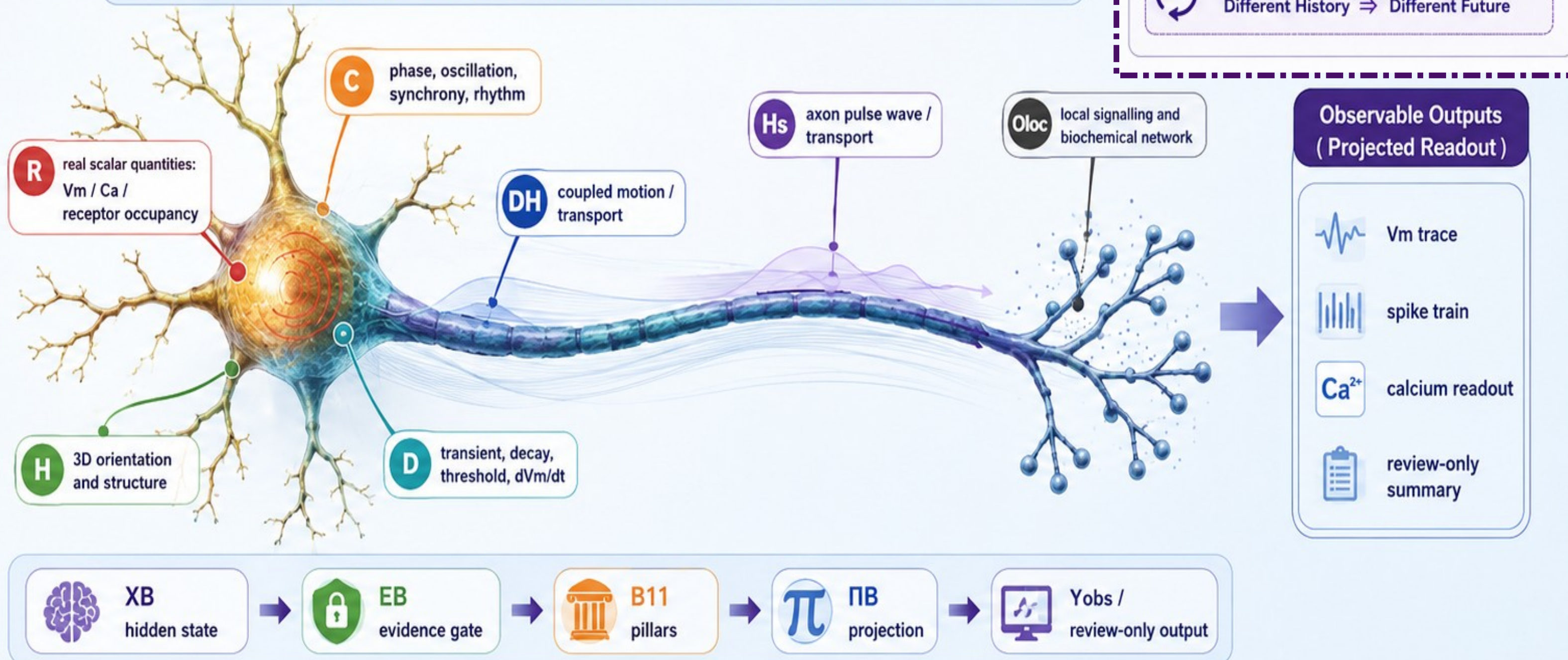
Tensor: Represents multi-directional interactions across domains, including biomarker-imaging, neuron-vascular, synapse-network, and cognition-biology coupling.

Connection: Defines transport and transition structure between biological states, supporting evidence-gated movement from hidden-state organization to bounded observable projections.

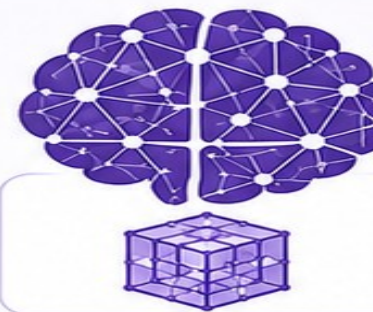
Bansal Algebra in Neuron Modelling

Stratified hidden-state layers, not a single observable signal

$$AB = R \oplus C \oplus H \oplus D \oplus DH \oplus Hs \oplus Oloc$$



Geometry-admissible hidden biological state



+ Admissible geometry
Topology + constraints across scales



+ Biological admissibility
Physiologic bounds, causality, consistency



+ Coupled hypercomplex structure
Cross-domain interactions



+ Temporal dynamics
Progression, plasticity, resilience

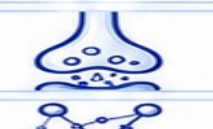


+ Unobserved factors
Compensatory mechanisms, latent heterogeneity

Review-only observable projections



Biomarker panels



Synaptic / cellular metrics



Connectivity / network maps



Perfusion / flow measures



Cognitive / clinical scores



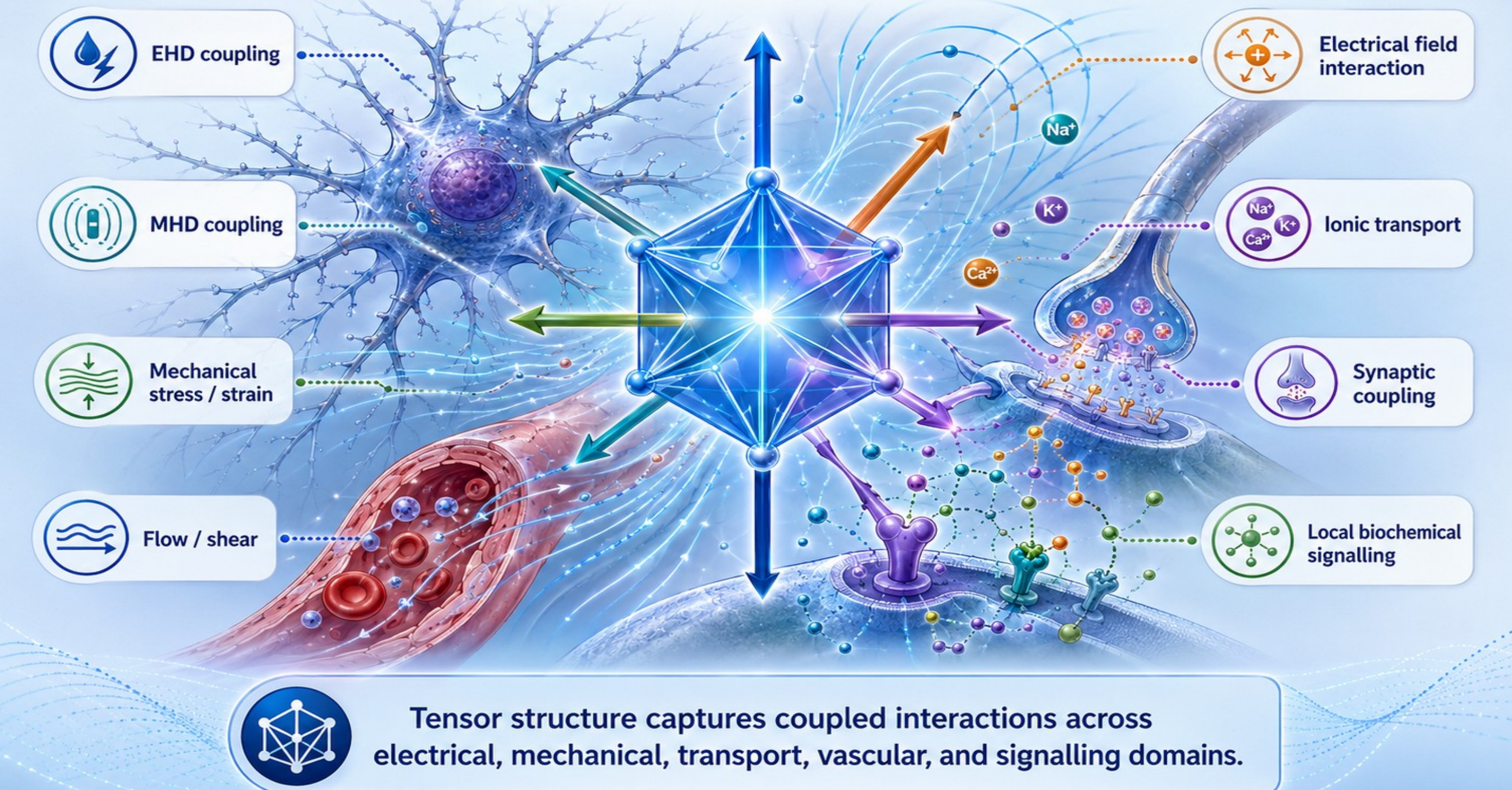
Imaging summaries



Dashboards / reports

Pillar 10 – Tensor

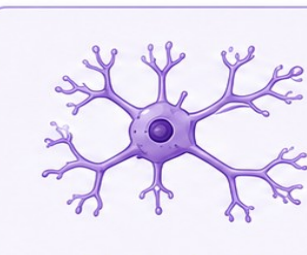
Multi-directional interactions



ENTROPY IN BIOLOGICAL SYSTEMS

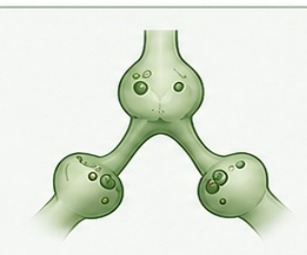
Entropy represents the degree of disorder, unpredictability, and loss of structured organization in the hidden biological state.

SOURCES OF ENTROPY IN NEURODEGENERATION



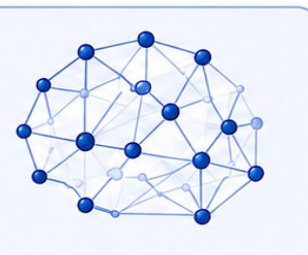
Molecular / Biomarker Disruption

Biochemical imbalance, oxidative stress, protein misfolding, inflammation.



Synaptic / Cellular Instability

Synaptic loss, receptor dysfunction, ion-channel dysregulation.



Network / Connectivity Breakdown

Loss of network efficiency, altered oscillations, desynchronization.



Vascular / Hemodynamic Variability

Reduced perfusion, flow instability, barrier dysfunction.



Cognitive / Clinical Uncertainty

Variability in symptoms, fluctuating trajectories, reduced resilience.

Conclusion

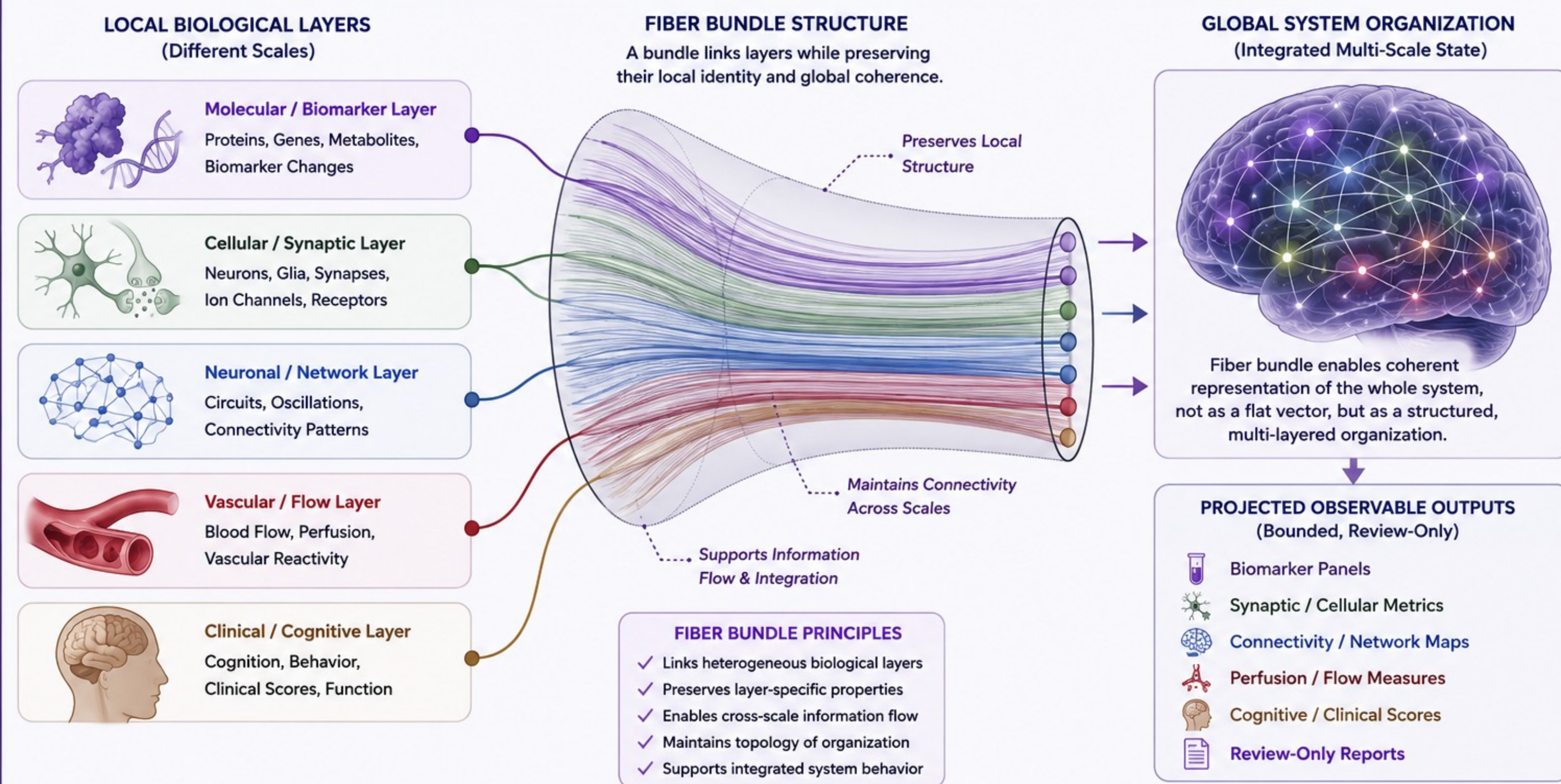
Bansal Neuron Modeling frames neurodegeneration as disruption of layered biological organization rather than a single diagnostic marker. Bansal Algebra organizes measurable and hidden biological phenomena into layered hypercomplex components, while the remaining Bansal pillars define their geometry, trajectory, curvature, operators, memory, entropy, fiber-bundle structure, tensor interactions, and connection pathways. Together, the eleven pillars link molecular/biomarker, cellular/synaptic, neuronal/network, vascular/flow, and clinical/cognitive layers into a geometry-admissible hidden biological state. Observable outputs such as biomarker panels, imaging summaries, network maps, perfusion measures, cognitive scores, membrane-potential traces, spike trains, calcium signals, and field features remain bounded projections rather than the complete biological state.

This framework is implemented as a full free software demonstration in the beta version of the BVIDAL Clinical Software Suite. The final output is review-only and does not claim standalone diagnosis, treatment recommendation, regulatory approval, or clinical validation.

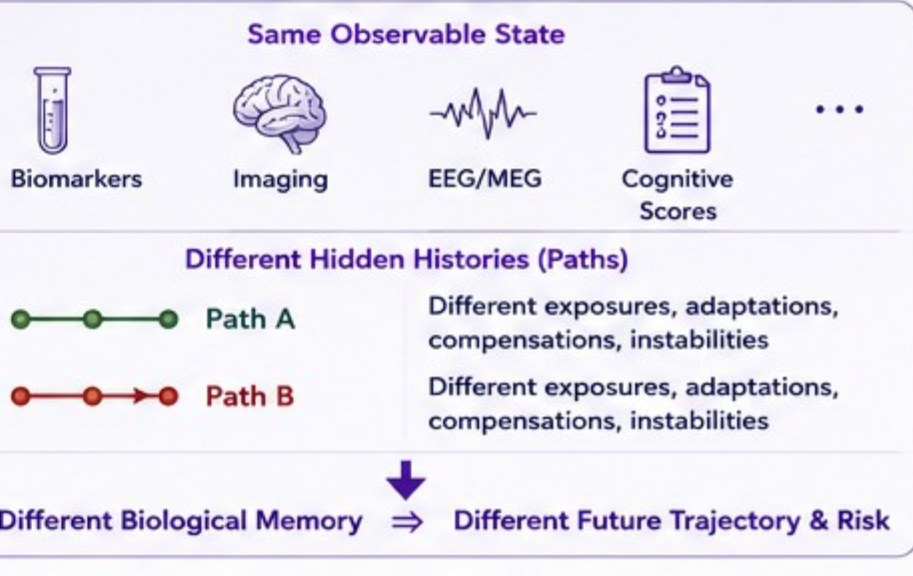
PILLAR 9 – FIBER BUNDLE

Connecting Local Biological Layers to Global System Organization

Pillar 9 (Fiber Bundle) links local biological layers across scales into a coherent, geometry-admissible structure — preserving identity, connectivity, and information flow.



MANIFESTATION OF HOLOMONY



KEY IMPLICATION
Holonomy explains why two individuals with the same current biomarkers or imaging can have different risks, trajectories, and responses—because their biological histories differ.

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