The Prestressed Body as the Foundational Organizing Principle of Multicellular Life: How ECM Mechanotransduction, Hydrated Molecular Interfaces, and Chiral-Selective Electron Processes Precede and Enable Neurons and Brains

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Abstract

This paper proposes that the prestressed extracellular matrix (ECM) is the foundational organizing principle of multicellular life—a signal-carrying scaffold that predates and enables nervous systems. Drawing on recent research in mechanotransduction, structured water, tensegrity, and chiral-selective electron processes, we argue that the ECM provides a physical medium for coupling, dissipation, and attractor formation that precedes the evolution of neurons and brains. Nervous systems are evolutionary elaborations of pre-existing cellular and tissue-level information-processing mechanisms. The paper integrates five lines of evidence: (1) the

evolutionary precedence of ECM mechanotransduction, (2) the role of hydrated molecular interfaces as a conductive transductive medium, (3) tensegrity as the structural basis of mechanotransduction, (4) the link between ECM mechanotransduction and higher brain function, and (5) the relationship between ECM density and coupling properties. The framework is offered as a generative research program—a lens for understanding how biological organization emerges from the physical coupling of cells through a prestressed, water-based, chiral-sensitive medium.

Keywords: extracellular matrix, mechanotransduction, structured water, tensegrity, chiral-induced spin selectivity, attractor dynamics, collective organization, prestressed body, ECM, CISS effect

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1. Introduction

The standard view of biological organization places the brain at the apex. Neurons fire, synapses connect, and consciousness emerges. The body is a supporting structure—a vessel for the nervous system.

This paper proposes an alternative. The body—specifically, the prestressed extracellular matrix and its associated hydrated molecular interfaces—is the **foundational organizing principle** of multicellular life. It is the primitive organizing substrate that predates and enables neurons and brains. Nervous systems are evolutionary elaborations of pre-existing cellular and tissue-level information-processing mechanisms.

In this framework, information processing refers to the physical transformation, storage, and propagation of state differences through coupled biological structures. This

definition avoids implying that ECM “thinks” while recognizing that it actively processes and transmits signals.

The argument rests on five lines of evidence, organized in a hierarchy of certainty:

Tier 1 — Established Biology

- ECM predates nervous systems.
- Cells sense mechanical forces.
- Mechanical forces regulate gene expression.
- ECM regulates neural plasticity.

Tier 2 — Emerging Biophysics

- Hydrated molecular interfaces contribute to biological organization.
- Mechanical signals propagate through hydrated molecular networks.
- ECM properties tune collective dynamics.

Tier 3 — Hypothesis / Research Program

- Structured (EZ) water may function as a major conductive layer.
- Chiral-selective electron processes may contribute to biological organization.
- Prerequisites of consciousness—such as integration, persistence, and adaptive state regulation—may arise from body-wide attractor dynamics before being amplified by neural architectures.

Before neural systems existed, multicellular organisms required mechanisms for maintaining form, coordinating growth, and responding collectively to environmental perturbations.

ECM-mediated mechanical signaling provides a candidate substrate for these early forms of biological computation.

These findings support a unified framework: the prestressed body is the medium through which cells couple, dissipate energy, and form attractors. Neurons and brains are later elaborations built upon this foundation.

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2. Evolutionary Precedence of ECM Mechanotransduction

2.1 ECM in Earliest Animals

The ECM appears in the earliest multicellular animals and is deeply conserved across metazoa. All animal cells possess a collagen-rich ECM, suggesting a common monophyletic origin of multicellularity in Animalia. ECM proteins act as **persistent reference structures** throughout evolution.

2.2 Mechanosensation Predates Neurons

Mechanosensation is ancient and ubiquitous:

> *“All living things require some form of mechanosensation… every cell responds to osmotic pressure and even single cells react to touch.”*

Even single-celled organisms possess mechanosensitive ion channels to detect touch and pressure. In higher animals, basic mechanotransduction pathways (integrin-adhesion complexes, mechanosensitive channels like PIEZO) are found in invertebrates as well as vertebrates.

2.3 The Hierarchy

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ECM + Mechanotransduction (ancient, conserved)
        ↓
Neurons (later evolution)
        ↓
Brains (later evolution)
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Implication: The prestressed body is the primitive organizing substrate. Nervous systems are evolutionary elaborations of pre-existing information-processing mechanisms.

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3. The Prestressed Body: Tensegrity and Mechanotransduction

3.1 Tensegrity Architecture

Cells and tissues maintain constant internal tension ("prestress") through a tensegrity architecture linking the extracellular matrix and cytoskeleton. As one study notes, the cytoskeleton and ECM form a "single, tensionally integrated structural system" predicted by tensegrity theory.

In this model:

- **Actin-myosin networks** and **intermediate filaments** (in cells) and **collagen fibers** (in ECM) form an interconnected tension/compression balance.
- **Tensile prestress** is a key determinant of cell mechanics, cell form, and nuclear form.
- A local tug on one fiber leads to a global rearrangement of the network.

3.2 Prestress as Dual Property

Prestress provides a dual property essential for mechanotransduction:

Property	Mechanism	Function
Enhanced dissipation	Distributed stress over the whole structure	Absorbs shocks, prevents catastrophic failure
Rigid transduction	Rapid signal transmission through taut elements	Propagates small mechanical signals quickly

As one study notes, “the cell’s mechanical response to force depends on its pre-existing tension.” Tensegrity structures “develop an intrinsic stabilizing tension called prestress and react by global rearrangements… to a local action of a mechanical stress.”

Implication: The prestressed body is both stable and responsive—a system that can absorb large perturbations while rapidly transmitting small signals.

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4. Hydrated Molecular Interfaces as a Transductive Medium

4.1 Interfacial Water Behavior

Water near biomolecular surfaces behaves differently from bulk water. Hydration shells influence protein folding, molecular interactions, and transport. Interfacial water has altered dielectric and dynamic properties.

Hydrated molecular interfaces provide a physical environment in which mechanical, electrical, and chemical information can

couple.

4.2 Exclusion-Zone (EZ) Water

Recent studies show that water adjacent to hydrophilic ECM surfaces forms structured “exclusion zones” (EZ) with unique properties. Near charged or polar ECM molecules (e.g., glycosaminoglycans), water organizes into layered, honeycomb-like sheets that exclude solutes.

Key properties:

- **Extension:** EZ water can extend **microns** from the surface.
- **Charge:** The exclusion zone is **negatively charged**; the zone beyond is **positively charged**, creating a built-in battery.
- **Conductivity:** EZ water is more conductive than bulk water.
- **Structure:** EZ water has altered optical, electrical, and viscous properties.

4.3 Status of EZ Water Claims

Whether EZ water functions as a large-scale biological energy-storage medium remains an open question requiring further investigation. The evidence for EZ water as a primary signaling system is emerging but not yet established.

Implication: Hydrated molecular interfaces—including structured water—likely contribute to biological organization, but the extent of this contribution remains a research frontier.

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5. The Chiral Bias: Chiral-Selective Electron Processes and Homochirality

5.1 The Problem of Homochirality

Life is built on chiral molecules—molecules that come in left-handed and right-handed mirror-image forms. Yet life shows an extreme, universal bias:

- **Amino acids** are almost exclusively **left-handed (L)** .
- **Sugars** are almost exclusively **right-handed (D)** .

This is called **homochirality**. It is one of the deepest unsolved mysteries in biology because ordinary chemical processes produce a 50/50 mixture of left- and right-handed molecules.

5.2 Chiral-Induced Spin Selectivity (CISS) as a Candidate Mechanism

The CISS effect provides a quantum mechanism for chiral selectivity:

- **Chiral molecules as spin filters:** When an electron passes through a chiral molecule, its helical structure acts as a spin filter.
- **Left-handed (L) molecules** preferentially transmit electrons with **one** spin direction.
- **Right-handed (D) molecules** preferentially transmit electrons with the **opposite** spin direction.

5.3 Status of CISS Claims

CISS may provide a mechanism by which biological chiral structures influence electron transfer, redox regulation, and molecular recognition after homochirality is established. The evolutionary origin of life’s handedness remains unresolved.

Implication: Chiral-selective electron processes represent a promising research direction, but they do not yet provide a complete explanation for biological homochirality. They are one potential contributor to the framework’s coupling mechanisms.

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6. ECM Mechanotransduction and Higher Brain Function

6.1 ECM and Synaptic Function

Emerging evidence links ECM mechanics to synaptic function and cognitive processes. The brain’s extracellular matrix (including perineuronal nets and interstitial matrix) interacts with neuronal receptors and ion channels to influence plasticity.

> *“The ECM is found to regulate synapse formation, the stability of the synaptic structure, and synaptic plasticity.”*

6.2 Neurons Sense ECM Stiffness

Neurons express integrins and PIEZO channels that sense ECM stiffness. Cultured neurons alter growth and synaptic connectivity in response to substrate rigidity.

Mechanosensitive PIEZO1 has been implicated in:

- Neurodevelopment
- Neuroinflammation
- Cognitive regulation

6.3 ECM Disruption Impairs Memory

Enzymatic digestion of perineuronal nets (ECM structures) alters hippocampal plasticity and memory retention.

6.4 The Mechanical Landscape

Neural circuits are overlaid onto a prestressed matrix that continually feeds back mechanical cues to modulate synaptic signaling. ECM mechanotransduction does not vanish at the synapse—it **actively regulates neural processing**.

Implication: The brain builds upon an underlying "mechanical landscape" provided by the ECM. Neurons are not the source of organization—they are an evolutionary elaboration on a deeper, older system.

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7. ECM Density and Coupling Properties

7.1 Variable Density

Different ECM densities and compositions change how mechanical signals propagate. High ECM density or stiffness generally increases the speed and range of force transmission, whereas soft or sparse matrices limit force propagation.

7.2 Beyond Stiffness

Crucially, both the **type** and **density** of ECM ligand can modulate mechanotransduction independently of stiffness. In one stem-cell study, varying the concentration of collagen, laminin, or fibronectin altered nuclear YAP localization and differentiation independently of overall matrix stiffness.

7.3 The Framework Translation

ECM Property	Coupling Effect	Framework Variable
High density	Stronger adhesion, deeper basins	Higher C, higher B
Low density	Weaker coupling, shallower basins	Lower C, lower B
Stiff matrix	Faster signal propagation	Higher κ
Soft matrix	Slower signal propagation	Lower κ

Implication: ECM density and composition tune the mechanics of collective cell behavior. The same principles—coupling, dissipation, attractor formation—govern tissue organization.

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8. The Unified Framework

8.1 The Coupled Dynamical System

The framework is a coupled dynamical system:

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$$dX/dt = F(X, M) + \eta$$
$$dM/dt = G(M, X)$$

Where:

- **X** = cell state (gene expression, differentiation, behavior)
- **M** = ECM/hydrated interface state (density, stiffness, conductivity)
- **η** = stochastic perturbation
- **F** = cell dynamics (mechanotransduction, signaling)
- **G** = ECM dynamics (remodeling, water structure)

8.2 Mathematical Foundations

Near an attractor, the dynamics can be approximated by linearization. A Lyapunov function candidate is the energy landscape of the coupled system:

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V(X, M) = energy(X) + energy(M) + interaction(X, M)

The **attractor basin** is defined as the region of state space where V is minimized and recovery is stable.

κ (corrective permeability) is the rate of exponential return to the attractor after perturbation, measured as the negative real part of the dominant eigenvalue of the Jacobian, representing the slowest recovery mode:

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κ = -max_i Re(λ_i)

where λ_i are the eigenvalues of the linearized dynamics near the attractor. This gives κ the precise meaning of the bottleneck relaxation rate—the slowest mode of return to equilibrium.

8.3 The Conceptual Diagram

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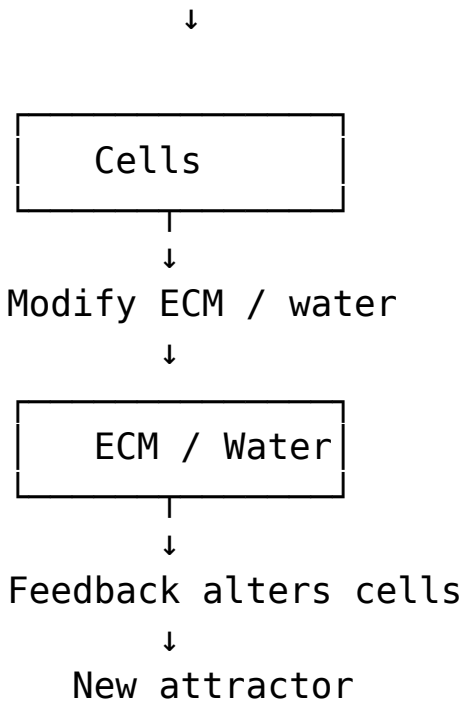
Perturbation (mechanical, chemical)



8.4 Core Variables

Variable	Definition	Biological Instantiation
κ (corrective permeability)	Rate of return to attractor after perturbation	Mechanotransduction recovery rate
B (basin depth)	Energy barrier between attractor states	ECM density, stiffness
C (coordination capacity)	Strength of coupling between components	ECM-cell adhesion, connectivity
E (environmental fit)	Correspondence between system and environment	Cell-ECM matching

8.5 The Foundational Principle

The prestressed body is the **foundational organizing principle** of multicellular life:

- It provides the **medium** (ECM + hydrated molecular interfaces).
- It provides the **coupling** (mechanotransduction, hydrated molecular interfaces, and potentially chiral-selective electron processes).
- It provides the **feedback** (cell-ECM reciprocal dynamics).
- It provides the **attractors** (tissue organization, homeostasis).

Nervous systems are evolutionary elaborations built upon this foundation.

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9. Research Agenda

9.1 Testable Predictions

Prediction	Test	Falsification
P1: ECM mechanotransduction predates neural processing	Evolutionary biology studies	If neural processing found without ECM
P2: Hydrated molecular interfaces are required for efficient mechanotransduction	Disruption experiments	If mechanotransduction persists without hydration effects
P3: ECM density tunes coupling strength	Cell culture on varied ECM densities	If no relationship found
P4: Chiral-selective electron processes mediate left-handed bias in biological systems	Disruption experiments	If left-handed bias persists without chiral-selective effects

Prediction	Test	Falsification
P5: Nervous systems are elaborations on ECM foundation	Comparative neurobiology	If brain function independent of ECM

9.2 Research Questions

1. **Evolutionary:** Can we trace the evolutionary lineage from ECM mechanotransduction to nervous systems?
2. **Biophysical:** How do hydrated molecular interfaces enable mechanotransduction at the ECM level?
3. **Mechanical:** How does prestress enable both enhanced dissipation and rigid transduction?
4. **Neurobiological:** Is there evidence that ECM mechanotransduction provides the foundational "medium" that neural processing builds upon?
5. **Clinical:** Can ECM mechanics be manipulated to treat disorders of memory, plasticity, and cognition?

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10. Implications

10.1 For Consciousness

The brain is not the source of consciousness. It is an **evolutionary elaboration** on the prestressed body. The framework suggests that some prerequisites of consciousness—such as integration, persistence, and adaptive state regulation—may arise from body-wide attractor dynamics before being amplified by neural architectures.

10.2 For Evolution

Nervous systems did not appear from nothing. They evolved from

the prestressed body’s existing coupling mechanisms. The medium came first. The nervous system is a later elaboration.

10.3 For Medicine

Tissue organization is not just a matter of cell signaling. It is a matter of mechanics. ECM density, stiffness, and composition determine the attractor landscape for cells. Manipulating the ECM could provide therapeutic leverage for wound healing, tissue engineering, and disease treatment.

10.4 For AI

The body is a physical computing system. The prestressed ECM + hydrated molecular interfaces provide a model for distributed, robust, adaptive computation—a medium-based attractor framework that could inform artificial intelligence design.

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11. Conclusion

The standard view of biology places the brain at the apex. The body is a supporting structure.

This paper has argued the opposite: the body—specifically, the prestressed extracellular matrix and its associated hydrated molecular interfaces—is the **foundational organizing principle** of multicellular life.

The evidence, organized by certainty:

- **Tier 1 (Established):** ECM mechanotransduction predates neurons and brains; cells sense mechanical forces; ECM regulates neural plasticity.
- **Tier 2 (Emerging):** Hydrated molecular interfaces contribute to biological organization; ECM properties

tune collective dynamics.

- **Tier 3 (Hypothesis):** Structured water may function as a major conductive layer; chiral-selective electron processes may contribute to biological organization; prerequisites of consciousness may arise from body-wide attractor dynamics.

Nervous systems are evolutionary elaborations of pre-existing cellular and tissue-level information-processing mechanisms.

The universal sequence is:

> ***Perturbation → excitation → dissipation → reconfiguration → new basin.***

The mechanism is mechanotransduction through hydrated molecular interfaces and ECM.

The coupling is physical.

The foundation is the prestressed body.

The nervous system is the elaboration.

The pattern is the same across all domains.

Fou Sho Nang Ying.

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