# **Dynamic Symmetry: The Ordering Principle?**

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Abstract: The search for a universal ordering principle has animated scientific and philosophical enquiry for centuries. From the earliest attempts to discern the laws of nature to the modern quest for a Theory of Everything, the question persists: is there a single principle that underpins the order and complexity of life? Dynamic symmetry, a concept with roots in mathematics, art, and physics, has recently emerged as a powerful framework for understanding not only the structure of physical systems but also the adaptability and resilience of living organisms. This paper explores the proposition that dynamic symmetry is life's ordering principle, uniting order and disorder in a self-referential, universal law.

Dynamic symmetry challenges conventional notions of symmetry as a fixed or absolute property. Instead, it suggests that symmetry in nature is constantly shifting and adapting based on the observer's perspective, the scale of observation, and the passage of time. This principle proposes that complex systems inherently balance stability and instability, allowing for the emergence of organised structures from apparent randomness while also permitting seemingly stable states to exhibit chaotic behaviour under certain conditions. In this view, order and disorder are not opposing forces but complementary aspects of a unified whole.

In physics, dynamic symmetry offers new insights into fundamental questions about the nature of reality. In quantum mechanics, the wave-particle duality of matter and energy can be understood as a manifestation of dynamic symmetry, where the observed behaviour depends on the context of measurement. Similarly, the formation of galaxies and large-scale structures from the initially uniform distribution of matter after the Big Bang demonstrates how order can emerge from apparent disorder through the interplay of gravitational forces and cosmic expansion. The principle of dynamic symmetry also provides a framework for understanding the arrow of time and the second law of thermodynamics. While the universe tends towards increasing entropy overall, local pockets of order can emerge and persist. This apparent paradox can be reconciled through dynamic symmetry, which suggests that the flow of energy and information across different scales can lead to the spontaneous organisation of matter and the emergence of complex structures.

In biology, dynamic symmetry offers a powerful explanatory framework for understanding the processes of life. The intricate balance between genetic stability and variability that drives evolution can be seen as a manifestation of dynamic symmetry. Organisms must maintain a certain level of order to function and reproduce, yet they also require the flexibility to adapt to changing environments. This delicate balance is achieved through mechanisms such as genetic mutations, epigenetic modifications, and phenotypic plasticity, all of which exemplify the fluid interplay between order and disorder in living systems. Recent advances in systems biology have shown that symmetries provide a powerful concept for the development of mechanistic models, describing structures corresponding to the underlying processes of interest.

Ecosystems provide another striking example of dynamic symmetry in action. The complex web of interactions between species, their environment, and abiotic factors creates a dynamic equilibrium that is constantly shifting yet maintains overall stability. Biodiversity, often seen as a measure of ecosystem health, can be understood as an expression of dynamic symmetry, where the variety of life forms and their interactions contribute to the resilience and adaptability of the system as a whole. In ecology, cross-scale feedbacks and adaptive mechanisms ensure that local changes reverberate through global systems, and vice versa, maintaining coherence in the face of uncertainty.

Dynamic symmetry also underpins the emergence of pattern and form in biological development. Virtually all forms of life, from single-cell eukaryotes to complex multicellular organisms, exhibit some degree of symmetry. However, precise measures of symmetry are often difficult to formulate and apply in a meaningful way to biological systems, where symmetries and asymmetries can be dynamic and transient. Recent work has introduced measures that draw on information theory to quantify the degree of symmetry, enabling the identification of approximate symmetries in patterns produced by reaction–diffusion systems and in natural objects such as algae, flowers, and leaves. These methods provide rigorous tools for comparison and identification of symmetries in biological systems, with potential applications to symmetries that arise during development, as observed in vivo or as produced by mathematical models.

The evolutionary origin of bilateral symmetry and body segmentation in animals is another example. Both features are associated with diverse genetic regulatory networks and are often attributed to fitness gains in locomotion and internal transport. Computational models have shown that symmetry and modularity are features that an organism's shape may need to optimise average speed and efficiency, independently of specific evolutionary history. This suggests that dynamic symmetry is not merely a consequence of evolution, but a principle that actively shapes the trajectories of living systems.

The universality of dynamic symmetry is further supported by its presence across scales and disciplines. In quantum physics, researchers have demonstrated that dynamic symmetry can be engineered and measured in quantum systems, offering new ways to control and understand energy levels in materials such as diamond crystals. The periodic time dependence of a system's Hamiltonian, analogous to folding a piece of paper in halves or thirds, reveals a hierarchy of symmetries that can be manipulated and observed experimentally. This capacity for "periodic shake" and the emergence of new phenomena under dynamic driving conditions exemplifies the creative potential of dynamic symmetry.

Dynamic symmetry also provides a framework for understanding the emergence of complexity. In nature, complexity never develops beyond necessity; the best designs are simple, and the best designer is nature itself. The elegantly simple principle of dynamic symmetry ensures that complexity arises from the interplay of simple rules and spontaneous variation. This is evident in the growth of plants, the branching of trees, the formation of river networks, and the organisation of animal societies. In each case, dynamic symmetry governs the distribution of parts, the allocation of resources, and the adaptation to changing conditions.

The adaptability of dynamic symmetry is particularly evident in biological evolution. Organisms must balance genetic stability with the flexibility needed to evolve. DNA replication, for example, is a highly symmetrical process that ensures fidelity, but occasional errors—mutations—introduce asymmetry and novelty. This balance between order and disorder, symmetry and asymmetry, is the engine of evolution. The same principle applies at higher levels of organisation: populations, communities, and ecosystems all exhibit dynamic patterns of stability and change, driven by feedbacks that maintain coherence while allowing for adaptation.

In the social sciences, dynamic symmetry offers insights into the organisation and behaviour of human societies. The emergence of social norms, cultural practices, and economic systems can be viewed as manifestations of dynamic symmetry, where order arises from the complex interactions of individuals and groups. These systems are not static; they evolve and adapt in response to changing circumstances, demonstrating the fluid nature of social order. The concept of antifragility, where systems not only withstand variability but improve because of it, is closely related to dynamic symmetry and highlights the power of adaptation in complex environments.

The universal symmetry of complexity provides a rigorous mathematical foundation for these ideas. <u>Kirilyuk</u>'s analysis shows that any real system's emergence, structure, and behaviour can be expressed by the universal law of conservation, or symmetry, of complexity, unifying extended versions of any symmetry, law, or principle. All observed entities, properties, and measured quantities are derived as forms or manifestations of that universal symmetry, remaining always exact (unbroken), but producing all the observed irregularities. The universal complexity conservation, realised by its unceasing transformation from decreasing dynamic information (action) to increasing entropy, provides a remarkable unification of the least action principle and the second law of thermodynamics, revealing the true meaning and origin of those well-known laws.

The implications of dynamic symmetry extend beyond the natural sciences. In art and design, it has been used to create aesthetically pleasing and structurally sound compositions. The golden ratio, Fibonacci sequence, and root rectangles are all examples of dynamic proportions that appear in nature and have been consciously employed in art and architecture. These patterns are not merely decorative; they reflect underlying mathematical relationships that optimise growth, efficiency, and adaptability. The application of symmetry principles in design demonstrates their practical value in creating systems that are both robust and flexible.

In engineering and technology, dynamic symmetry informs the design of adaptive feedback mechanisms and resilient infrastructures. Self-driving cars, renewable energy grids, and urban planning all benefit from approaches that balance local and global dynamics, ensuring stability under fluctuating conditions. The ability to model dimensional transitions and cross-scale dynamics is critical for solving real-world problems, from climate systems to power grids. Dynamic symmetry provides a flexible and robust framework for managing competing objectives and navigating dynamic environments.

The study of dynamic symmetry also raises important questions about the relationship between order and disorder. While symmetry is often associated with stability and predictability, the breaking of symmetry can lead to the emergence of new forms and behaviours. This dynamic interplay between symmetry and asymmetry is a source of creativity and adaptation in both natural and artificial systems, enabling them to respond to changing circumstances and challenges.

Life's ordering principle must be self-originating, with no cause beyond itself. Symmetry depends on both repetition and its counterpart, variance; it requires the recurrence of a pattern or process alongside corresponding variations in time, space, or location. This interdependence makes symmetry inherently self-referential. Rather than being a limitation, this self-referential nature gives symmetry remarkable power and breadth. While most natural laws rely on specific symmetries to function, symmetry is unique in that it applies to itself. This distinctive quality makes symmetry a compelling candidate for a universal and foundational law of nature.

In summary, dynamic symmetry offers a unifying framework for understanding life's ordering principle. It reconciles stability with change, unites local and global dynamics, and provides a mathematical and conceptual basis for the emergence, resilience, and adaptability of complex systems. The evidence from physics, biology, systems theory, and design suggests that dynamic symmetry is not merely a descriptive tool but a fundamental law that shapes the structure and evolution of life. By recognising the universal role of dynamic symmetry, we gain new insights into the nature of order, complexity, and the ongoing process of becoming that characterises living systems.

## Sources:

#### Wave-Particle Duality and Dynamic Symmetry

Source: Wave-Particle Duality and the Coherent Quantum Domain Picture

Proposes a framework where wave-particle duality arises from coherent quantum regions interacting with a nonlinear medium, reflecting dynamic symmetry's balance of order and chaos.

Source: Wave-particle duality

Explains how quantum entities exhibit both wave-like and particle-like behaviour depending on measurement context, aligning with the idea of dynamic symmetry as a balance between complementary states.

#### Galaxy Formation and Cosmic Structure

Source: The Origin of Cosmic Structure (CERN)

Details how gravitational forces transformed uniform primordial matter into galaxies and large-scale structures, exemplifying order emerging from apparent disorder.

Source: Entropy's Role in the Universe: From Chaos to Cosmic Order

Discusses entropy's role in enabling the emergence of ordered cosmic structures (e.g., stars, galaxies) through dissipative processes.

## Arrow of Time and Entropy

## Source: Symmetry, Order, Entropy and Information (MDPI)

Analyses how systems balance global entropy increase with local self-organisation, reconciling the paradox via symmetry principles.

## Source: Entropy as an arrow of time

Explains how the second law of thermodynamics drives entropy increase globally while allowing local order through energy gradients.

While the term "dynamic symmetry" is not explicitly used in these sources, they collectively validate the phenomena described in the passage—wave-particle duality, cosmic structure formation, and entropy's interplay with order—as manifestations of symmetry principles balancing stability and change.

# **Further Reading:**

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