Edge of Chaos: Exploring Dynamic Symmetry Theory and the Science of Complexity

The Royal Society, London – 15 May 2026

In-person attendance
Venue: Conference Room, The Royal Society, 6–9 Carlton House Terrace, London SW1Y 5AG. Attendees will have full-day access to all sessions, free lunch and refreshments, a printed programme, and opportunities for informal conversation with speakers and other participants.

Online attendance
A live Zoom webinar will carry all talks and the closing discussion.

Programme
08:30–09:00 Registration

09:00–09:30 Benedict Rattigan (Director, The Schweitzer Institute)
'Framing Dynamic Symmetry Theory and the Dynamic Symmetry Index'

09:35–10:05 Professor Predrag Cicovacki (Professor Emeritus of Philosophy, College of the Holy Cross)
'Dynamic Symmetry and the Challenge of Being Human'

10:10–10:40 Professor Tim Palmer FRS (Royal Society Research Professor in Climate Physics, Oxford University)
'Order and Chaos on the Lorenz Attractor'

10:45–11:00 Coffee

11:00–11:30: Professor Daniela Bortoletto OBE (Head of Particle Physics, Oxford University)
'Precision Higgs Physics at the LHC and HL-LHC: Probing the Higgs Potential, Self-Coupling, and Symmetry Breaking'

11:35–12:05 Professor Denis Noble CBE FRS (Emeritus Professor of Cardiovascular Physiology, Oxford University)
'Dynamic Symmetry, Biological Relativity and the Harnessing of Stochasticity'

12:10–12:40 Professor Gianluca Gregori (Professor of Physics, Oxford University)
'Star Makers and Beyond: Scaled-Down Lab-Grown Astrophysics'

12:40–13:25 Lunch

13:25–13:55 Professor Tim Lenton OBE (Chair in Climate Change and Earth System Science; Founding Director, Global Systems Institute, University of Exeter)
'Tipping Points'

14:00–14:30 Gisella Marinuzzi (Associate Director, The Schweitzer Institute)
'*Dynamic Symmetry and the Design of More Adaptive and Effective Public Institutions'*

14:35–15:05 Dr Chiara Marletto (Research Fellow, Wolfson College, Oxford University)
'*Beyond Quantum Computation: Constructor Theory' (online)*

15:05–15:20 Break

15:20–15:50 Professor Alexander Lvovsky (Professor of Physics, Oxford University)
'Coherent Ising machines: self-assembling solutions to discrete optimization problems emerging from quantum chaos'

15:55–16:25 Dr Igor V. Ovchinnikov (UCLA)
'Topological Supersymmetry Breaking by Noise-Induced Instantons and the Edge of Chaos' (online)

16:30–17:00 Concluding Comments

Biographies

Benedict Rattigan is Director of the Schweitzer Institute, an environmental-ethics think tank affiliated with Peterhouse, University of Cambridge. His work brings together ethics, symmetry and the study of complex systems.

Professor Predrag Cicovacki is a philosopher whose work engages questions of metaphysics, ethics and philosophical anthropology. At this seminar he approaches dynamic symmetry as a framework for understanding the challenge of being human, while probing its reach, limits and deeper philosophical commitments.

Professor Tim Palmer FRS is a physicist in the Department of Physics at the University of Oxford. His work spans nonlinear dynamics, weather and climate prediction, and foundational questions in physics. At this seminar he uses the Lorenz attractor to explore order, chaos and the conceptual background of edge-of-chaos thinking.

Professor Daniela Bortoletto OBE is a physicist at the University of Oxford. Her research is associated with fundamental physics and experimental investigation at the smallest scales of matter. Her contribution brings high-energy and foundational perspectives into dialogue with the seminar's wider themes of order, instability and structured change.

Professor Denis Noble CBE FRS is a leading British biologist and physiologist, and a Fellow of the Royal Society. He is well known for his work on biological relativity, multi-scale causation and the role of stochasticity in living systems. His contribution examines how living organisms harness randomness rather than merely resisting it.

Professor Gianluca Gregori is a physicist whose work engages plasma physics and high-energy-density systems. His participation contributes a perspective from contemporary physics on how complex behaviour emerges under extreme conditions and how large-scale order can arise from highly dynamic processes.

Professor Tim Lenton OBE is a climate scientist known for his work on Earth-system dynamics, tipping points and planetary-scale change. His talk considers whether recent evidence on climate tipping points, and the possibility of positive tipping in society, can be illuminated through the lens of dynamic symmetry.

Gisella Marinuzzi works on questions of institutional design, governance and animal protection. Her seminar paper uses the proposed Animal Protection Commission as a case study for testing whether dynamic symmetry theory and the Dynamic Symmetry Index can guide the design of more adaptive and effective public institutions.

Dr Chiara Marletto is a theoretical physicist associated with work on constructor theory and the foundations of quantum theory. Her contribution asks what lies beyond quantum computation and considers how a framework based on possible and impossible transformations may intersect with the seminar's broader concern with invariance, transformation and dynamic balance.

Professor Alexander Lvovsky is a physicist whose work spans quantum optics and the foundations of quantum information. His contribution brings a rigorous physical perspective to questions about coherence, transformation and the relation between order and fluctuation in complex systems.

Dr Igor Ovchinnikov is a theoretical physicist whose work focuses on stochastic dynamics, chaos and topological approaches to dynamical systems. His seminar contribution examines edge-of-chaos regimes through the supersymmetric theory of stochastic dynamics and considers how such work might sharpen or challenge phenomenological approaches such as DST and the DSI.

Statement of aims

This seminar has three linked aims.

First, it aims to test whether dynamic symmetry theory can serve as a serious cross-disciplinary framework for understanding systems that must remain both stable and capable of change. Rather than treating order and disorder as simple opposites, the meeting asks whether many adaptive systems depend on a structured coupling between stabilising and exploratory processes.

Second, it aims to place that framework under real intellectual pressure. The meeting is not organised as a celebration of a finished doctrine. It is designed as a critical conversation in which physicists, biologists, philosophers and policy thinkers examine whether the language of dynamic symmetry genuinely clarifies phenomena in their own domains, or whether it risks becoming too loose, metaphorical or overgeneralised.

Third, it aims to explore whether these ideas can become more precise and operational. A central question running through the day is whether the proposed Dynamic Symmetry Index (DSI) can become a useful comparative and diagnostic tool for tracking adaptability, resilience and breakdown across different kinds of system.

The institutional and policy contributions ask whether the same framework can guide design in the social world, where resilience depends not only on explanation but on governance, measurement and judgment. The concluding comments will draw these strands together, sketching a possible research agenda around dynamic symmetry theory and the Dynamic Symmetry Index and indicating where further work, criticism and refinement are most needed.

Conceptual note

Dynamic symmetry: a one-page summary

Dynamic symmetry begins from a simple but far-reaching intuition: many systems survive, adapt and remain recognisable over time not by preserving perfect order, and not by dissolving into disorder, but by sustaining a workable relation between the two.

In this framework, symmetry is understood less as a static pattern than as an ongoing activity. A system "does symmetry" when it maintains enough coherence to hold together while also permitting enough variation to respond to changing conditions. The key question is therefore not whether a system is orderly or chaotic in the abstract, but how its stabilising and exploratory tendencies are coupled.

Stabilising processes are those that preserve structure, identity, constraint or repeatability. In different domains these may include homeostasis, inhibitory control, institutional rules, memory, geometric regularity or feedback mechanisms that damp disturbance.

Exploratory processes are those that introduce variation, novelty, fluctuation or search. These may include mutation, stochasticity, experimentation, improvisation, decentralised decision-making, or random perturbation.

Dynamic symmetry theory proposes that many complex adaptive systems function best when these two classes of process are neither fully separated nor allowed to overwhelm one another.

Too much stabilisation can make a system rigid, brittle or incapable of learning. Too much exploration can make it noisy, unstable or unable to preserve form. Between those extremes lies a narrower and often shifting zone in which systems can remain coherent while still adapting.

This is one reason the seminar engages the language of the edge of chaos. In complexity science, that phrase names regimes where systems are neither frozen into repetitive order nor dissolved into randomness, but capable of rich, flexible behaviour. DST shares this broad intuition, but seeks to refine it by asking not merely where a system sits on a spectrum, but what kinds of opposing processes are dynamically linked within it.

The theory is intentionally cross-disciplinary. In biology it may illuminate how organisms harness stochasticity without losing organisation. In neuroscience it may help describe brains that are ordered enough to integrate information yet variable enough to remain responsive. In climate science it may contribute to thinking about tipping points, thresholds and resilience. In institutions it may help diagnose when bureaucracy has become over-rigid, or when flexibility has turned into drift.

To make such claims testable, the seminar also introduces one concrete proposal for quantifying this balance: the Dynamic Symmetry Index (DSI).

The DSI is conceived as a normalised, empirically calibratable measure that combines paired metrics of order and disorder in order to estimate how near a system is to a dynamically balanced regime. It is not a claim that one formula will solve all domains. Rather, it is an attempt to create a disciplined method for comparing balance-in-motion across different cases.

At its most ambitious, DST is not just a model of complex systems but a proposal about how to think about them. It encourages attention to feedback, reciprocity, balance-in-motion, multi-scale interaction and tensions that are not always reducible to simple either-or choices.

The Law That Binds the Living Universe

By Denis Noble FRS

When Benedict Rattigan first came to see me in 2019 to discuss his developing work on what he called *dynamic symmetry theory*, I could scarcely believe what I was hearing. Some three years earlier, during a lecture at the Royal Society and in apaper that followed, I had advanced an idea that living systems owe much of their adaptability to what classical genetics had often treated as its opposite—randomness. Idescribed this as the *harnessing of stochasticity*: the use of the unpredictable to generate stability, adaptation, and creativity in biological systems.

Rattigan, emerging from an entirely different tradition, was attempting to articulate the same intuition in mathematical and philosophical terms. A philosopher by training, he was constructing an elegant model of coherence showing how order and disorder are not opposing poles but necessary partners in evolution.

The moment he described his approach, I recognised our shared insight. Two distinct disciplines—biology and philosophy—had converged on a single generative principle. The experience was one of those rare moments of intellectual contact in which the boundaries between fields quietly dissolve.

From symmetry in form to symmetry in process

Our conversations led to our editing *The Language of Symmetry* (Routledge, 2023), co-authored with the physicist Afiq Hatta. That book brought together an unlikely circle of Oxford University professors: physicists, mathematicians, biologists, and philosophers. All were exploring how balance and asymmetry interweave in the structure of reality—from the curve of galaxies and the proportion of the human body to the architecture of music and the self-organisation of embryos.

In editing that collection, we began tosee that symmetry is not merely an aesthetic quality, a property of perfect forms or golden ratios; it is the grammar of emergence itself. True beauty, whether in aspiral nebula or a genetic code, is never static. It lives in the dynamic tension between regularity and deviation.

Since then, Rattigan's theoretical formulation—now often referred to as Edge theory—has developed considerably. His *Dynamic Symmetry Index (DSI)* provides a numerical expression of the balance between order (O) and disorder (D) through time:

$$DSI(t) = 1 - aO(t) - \beta D(t)$$

When order and disorder coexist in measured proportion, the system achieves coherence, expressed as a DSI value approaching 1. This may look disarmingly simple, but the equation captures something profound: the delicate poise that all complex systems—from weather patterns to neuronal firing—must sustain to remain alive.

By plotting DSI through time, one can reveal the rhythm by which systems continually correct themselves, oscillating between stability and disruption. Too much order and vitality declines; too much disorder and coherence breaks down. Life, cognition, ecosystems, economies—all thrive near this dynamic edge of chaos. It is, in the most literal sense, the rhythm of life itself.

The harnessing of chance

In genetics, dynamic symmetry gives mathematical structure to what I once observed empirically: that noise can be creative. Within living cells, molecular systems use randomness not as error but as raw material. Protein folding, gene regulation, and molecular signalling all carry elements of stochastic movement. These fluctuations allow life toexplore possibility space —to experiment with configurations until adaptive order emerges.

When a cell divides, when a neuron fires, when mutation occurs, it is not the suppression of uncertainty but its skilful management that produces resilience. The genome is not a blueprint that dictates the future; it is an improvisational score interpreted anew each generation. Dynamic symmetry provides the analytical language for that dance.

The same principle extends beyond genetics. In the heart's electrical rhythm, variation prevents pathological rigidity; in neural synchrony, small disruptions help organise consciousness; in the evolution of species, random mutation fuels natural selection. Everywhere we look, coherence depends on the controlled presence of noise.

Life, therefore, is not the negation of uncertainty—it is its orchestration.

Ancient insight, modern synthesis

Through dialogue with Rattigan, I came to see that our insights traced back to very ancient intuitions. Across centuries, Eastern and Western thought have recognised an oscillatory structure to existence. In the Chinese 陰陽 (yin-yang) tradition, harmony arises from the continuous interplay of complementaries, rather than the victory of one pole over another. In the Heraclitean *logos*, order itself is born of tension. The Greek word for "harmony"(*harmonia*) originally meant "fitting together of opposites".

What dynamic symmetry accomplishes is to translate those metaphors into mathematical and empirical language. It transforms poetry into testable prediction without draining the poetry away. This marriage of reason and intuition reminds us that science, at its best, is not a disenchantment of the world but a deepening of wonder.

As biological knowledge becomes ever more quantitative—through genomics, imaging, and systems biology—we risk losing sight of the qualitative thread that binds the story together: the unity of process. Dynamic symmetry provides that unifying thread, linking the elegance of proportion tothe dynamics of life.

A convergence of disciplines

The enthusiasm for this framework has grown quickly. In 2022, Rattigan and I co-hosted a conference at the British Museum devoted to *The Language of Symmetry* and its broader implications for science, culture, and design. Physicists discussed conservation laws; musicians spoke of harmonic flow; artists demonstrated fractal patterns in brushstroke distributions; geneticists explored correspondence between molecular feedback loops and musical resonance.

What became clear was that each discipline, for all its differences, speaks a version of the same language: symmetry as a conversation between constraint and creativity. We left convinced that collaboration between scholars of art and scientists of life is not ancillary, but essential to understanding the principles by which nature itself composes.

Building on that success, a meeting to be held at the Royal Society in May 2026 will explore dynamic symmetry as a cross-disciplinary principle. Scholars and researchers from physics, biology, computer science, philosophy, musicology and theology will gather to investigate how the balance of order and disorder manifests in their respective domains. I am honoured to take part. For Oxford scientists, it will be an opportunity to test theory against evidence; for artists and philosophers, a chance to experience science as a living art.

Coherence beyond reductionism

The historical significance of this effort may be immense. For three centuries modern science has prospered through division—into physics, chemistry, biology, psychology, and the humanities. That reductionist strategy yielded great power but also fragmentation. The cost of carving nature into specialised parts is the loss of unity.

Dynamic symmetry challenges that fragmentation. It offers aunifying grammar as Newton's laws once did for motion, including not only the physical but also the biological and cognitive dimensions of reality. Einstein unified geometry with energy; Darwin unified heredity with selection; dynamic symmetry may unify change itself—showing that coherence everywhere operates through the same corrective oscillation.

This hypothesis is now being explored through modelling projects across Europe and Asia. In plasma physics, the DSI is applied todescribe turbulence and the emergence of stable vortices. In ecology, it is used to quantify forest resilience after climate disturbance. In neuroscience, researchers employ it to study temporal coherence in EEG data during attention and creativity. The results repeatedly hint at structural self-similarity: nature appears to reuse the same rule of harmony at vastly different scales.

Implications for biology and beyond

The implications for genetics, and indeed for the life sciences, reach beyond mechanism. The classical view treated randomness as noise—something to be averaged out. Yet living systems run on fluctuation. The DSI reveals how spontaneous variability generates conditions for adaptation. Genes and cells, organs and organisms all operate through feedback that stabilises the whole while granting freedom to the parts.

This understanding forces us to redefine the human position in nature. We are not spectators mapping external phenomena but expressions of the same recursion. The heartbeat that sustains our existence, the neural waves that produce our consciousness, and the ecological cycles that support life are all sequences in one vast symphonic movement—the universe maintaining coherence through dynamic symmetry.

In this light, the harnessing of stochasticity becomes more than a biological mechanism; it is a cosmic principle. Just as stars form from gravitational collapse balanced against thermal expansion, so too does thought emerge from competing patterns of order and disorder. Between the determinism of physical laws and the openness of possibility, life finds its creative corridor.

The philosophical horizon

Philosophically, dynamic symmetry invites us to see reality not as a collection of things but as a network of relations. Existence becomes a verb, not a noun. The foundations of being are no longer static substances but dynamic interactions.

This vision resonates strongly with recent developments in complexity science, quantum biology, and even cognitive neuroscience, all of which increasingly treat systems as contexts that evolve through feedback. It also recalls an older lineage of thought—from Leibniz's monads to Whitehead's process philosophy—suggesting that the universe is composed of *events* rather than objects. Dynamic symmetry integrates that heritage with the proofs of modern empiricism.

For me as a biologist, this is more than intellectual satisfaction. It points toward a renewed ethics of science. If coherence emerges through relationship, then cooperation—not competition—becomes the measure of vitality. Evolutionary success lies not in domination but in mutual adaptation; progress is translation between complementary differences.

A revolution in understanding

Having watched revolutions in molecular biology, systems physiology, and theoretical genetics, I sometimes hesitate to assign the same word to yet another framework. But dynamic symmetry may justify it. If confirmed empirically, it would complete a circle that began long before genome sequencing or quantum computation—a circle that joins the mathematical and the mystical, the physical and the philosophical.

The world it discloses is not a machine running down toward entropy, but a living continuum constantly regenerating itself. Entropy and negentropy are not enemies; they are alternating phases of a greater process. The cosmos expands, cools, and organises simultaneously. Matter condenses into complexity; life reflects upon itself; understanding becomes another form of self-organisation.

We therefore stand, perhaps, at the dawn of a new synthesis—a science not of classification but of connection. Dynamic symmetry, far from being an abstract formalism, may become the intellectual foundation for an ecological civilisation: one that recognises balance as the condition of existence and stochasticity as its creative agency.

The road ahead

The next few years will be decisive. Advances in artificial intelligence and computational modelling now make it possible tosimulate the DSI across billions of datapoints, enabling us to trace coherence in real time. I expect that future research, incorporating quantum computation and biological feedback models, will clarify the precise mathematics linking noise, feedback, and emergent order.

Our upcoming Royal Society seminar will draw on such results to explore how far the law applies. Does it extend to planetary systems? To economics or language evolution? Can it inform medicine and mental health by identifying zones of optimal coherence in body and mind? These are open questions, but the enthusiasm of colleagues from multiple fields suggests that exploration will be vigorous.

The pulse of balance

Reflecting on a lifetime in science, I am struck by how the biggest leaps of understanding occur not through conquest but through synthesis. The greatest discoveries reveal what was already before our eyes but unseen: the pattern behind patterns.

Dynamic symmetry may be that discovery for our time. It teaches that every act of creation, from cell division to artistic inspiration, participates in the same geometry of balance. We are not observers standing apart from nature; we are its conversation made conscious.

If that is true, then this principle could herald not merely a scientific advance but a shift in worldview—as momentous as Copernicus's realisation that Earth itself is not the centre of the universe. The centre, it turns out, is everywhere dynamic equilibrium holds.

Professor Denis Noble CBE FRS
Department of Physiology, Anatomy and Genetics, University of Oxford
Fellow of Balliol College

Edge of Chaos: Exploring Dynamic Symmetry Theory and the Science of Complexity is organised by The Schweitzer Institute (https://schweitzer.institute) in collaboration with *OXQ: The Oxford Quarterly Journal of Symmetry & Asymmetry* (https://oxq.org.uk)

Videos of the day's talks will be made available on both organisations' websites. To access the 'Edge of Chaos' Zoom webinar, see overleaf.

For further details and all press enquiries, contact nathanjones.pr@gmail.com