THE GUY FOUNDATION

Water as a quantum biomolecule

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(Eds.)

Abstract proceedings of the 2025 Spring Series

Driving innovation in medicine through quantum biology

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Introduction to the 2025 Spring Series

The Guy Foundation team

Water plays a pivotal role in sustaining living organisms. Despite its deceptively simple structure, water, in its interaction with biological materials such as proteins and membranes, behaves in complex ways that are as yet imperfectly understood. Insight into the structure and function of this 'biological water' seems integral to our better understanding of how life works. As such the 2025 Spring Series aimed to investigate water in the biological context from a number of different angles.

The series began with an introduction by Dr Philip Kurian from the Quantum Biology Laboratory at Howard University. Philip outlined the complex physics of water, and how this physics is important in biology. Water, for instance, has strong electrical properties, such as conductivity and polarity, making it an interesting medium in the context of bioelectricity, the importance of which we highlighted in the 2024 Autumn Series. The structure of water and the way that it is organised and ordered in the biological environment of the cell differs from bulk water in ways that may be essential for life and, indeed, may have facilitated the origins of life.

The physics of water in the context of the cellular environment was further developed by Dr Ali Hassanali, from The International Center for Theoretical Physics in Trieste, who introduced ideas relating to water at different interfaces such as soap bubbles and how these might be used to model the membranes so ubiquitous in biology. The interaction of water with biological materials such as proteins is complex in ways that are as yet not well understood. Water appears to play a pivotal role in enabling chemical reactions integral to biological processes. This is particularly interesting from a quantum mechanical point of view and in the third session of the series, Dr Nathan Babcock, from Howard University, explored the quantum effects of water associated with proteins, in particular the importance of order in biological water.

And finally, the series addressed the interaction of light and water in the biological context, with presentations from Dr Robert Fosbury, from UCL and Emeritus Astronomer at the European Southern Observatory (ESO) and Professor Alistair Nunn, from The Guy Foundation and University of Westminster. Both light and water play essential roles in biology, though their synergistic effects are less well documented. The therapeutic effects of near infrared and infrared light, and the mechanism of action of photobiomodulation, have recently been suggested to potentially be due to interfacial water rather than light interacting with proteins directly.

The series concluded with a presentation of insights and implications regarding water's role in biology from Professor Wayne Frasch, Arizona State University, followed by a wide-ranging and thought-provoking roundtable discussion.

Introduction to The Guy Foundation

Professor Geoffrey Guy

Founder and Chairman, The Guy Foundation

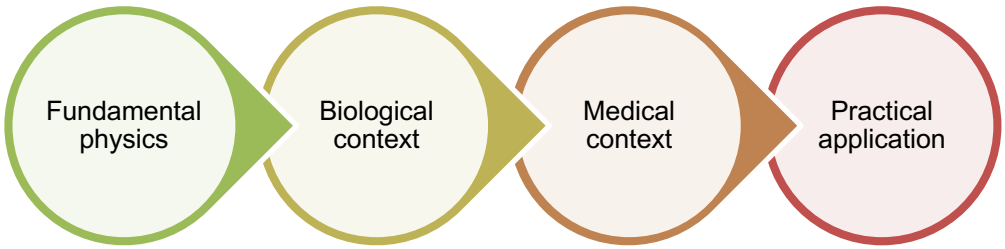
The Guy Foundation supports and promotes the investigation of quantum effects in biology, with the aim of improving our understanding of disease and thus medicine. Our belief is that significant quantum effects may well have been essential for the origins of life as well as the evolution of complex living organisms and thus a better understanding would help unlock new ways of tackling the health and disease issues that we see today.

With the development of technology, the study of quantum effects in biology has been gaining rapid pace in recent years. Classical pharmacology-based explanations for the effects of medicines remain insufficient; we aim to develop research into the effects of electromagnetic fields (both endogenous and exogenous) on biological systems. This will expand the conventional 'ball and stick' or 'lock and key' mechanisms which dominate our understanding of physiological processes, including the action of many pharmaceutical interventions. To this end we focus on the role of intracellular bioenergetics and the role of mitochondria from the point of view of dissipative thermodynamic and quantum theories. In short, if significant quantum effects are part of life, the failure to maintain this state probably plays a role in disease and ageing, and will thus be of importance to medicine.

We have also identified space travel as a key area that will benefit from a greater knowledge of the role that fields play in biology. If life is dependent on significant quantum mechanisms to function, then optimal function will be coupled to the planetary environment in which it evolved: a "Goldilocks zone" of environmental conditions. The Foundation believes that a focus on the ways in which the electromagnetic, gravitational and other effects of the space environment can be potentially mitigated, will optimise the health of astronauts and future passengers. This research would also accelerate progress in quantum biology and the advancement of medicine in general.

It is clear to us that the next generation of significant steps in medicine will need to engage with quantum biology. Our role at the Foundation is to help facilitate this mindset shift to bring quantum biology into the mainstream of medicine for the benefit of healthcare issues including ageing, neurodegeneration, metabolic syndrome, neuropsychiatric disease in the young, cancer and others. The Guy Foundation thus leads, supports and contributes to quantum biological and related research with the ultimate aim of advancing the development of new medical diagnostics and therapeutics.

The Foundation believes this advancement can be achieved in a number of ways, which is reflected by the research we fund as well as the topics we address in our scientific symposia. Our approach is summarised as encompassing research from bench to bedside:



Our priorities encompass the spectrum of theoretical, experimental, and practical advances. Understanding the fundamental physics (e.g., quantum mechanics, electrodynamics, thermodynamics) is important. More specifically we aim to understand this physics within the biological and physiological contexts, with the emphasis on furthering the study of medicine. Overall, we would like to see this knowledge translated and applied in clinical practice.

The Foundation therefore aims to provide a platform and a forum for upstream push through and downstream pull through of the understanding of the role of quantum effects and bioenergetics in biology in health and disease. We have curated and fund a collaborative research group to further investigate these interests, to advance the course of useful knowledge towards the mainstream and bring it to the attention of more conventional funders. We convene a programme of scientific meetings and publications that incorporates the diverse aspects of the field and facilitate engagement from scientists across relevant disciplines.

Abstract Proceedings

These are abstracts of a series of talks, hosted by The Guy Foundation, that were given online to an invited audience during the spring of 2025.

They have been written by the presenters and have not been formally peer-reviewed. We hope you enjoy them; video recordings of the lectures are available on the Foundation's website **www.theguyfoundation.org**. To receive notifications about new videos, subscribe to our **YouTube channel**.

The physics of water in biology

Dr Philip Kurian

Howard University

View the video recording **here**.

This lecture addresses the role of “the elephant in the room” played by water in the origins, organization, and development of living systems. Unlike all other solvents, water should seem wondrously weird to us, as it exhibits a suite of properties crucial to life's emergence, including: extraordinarily high melting and boiling points, the highest latent heat of vaporization of any known solvent, ice floating on water, all three phases coexisting across Earth surface temperatures, and a higher relative permittivity (dielectric constant) than almost all pure liquids. The relative strengths of various types of chemical "bonds" are compared, highlighting the significance of the hydrogen bond, entropic forces organizing nonpolar solutes, and bespoke hydrogen bond networks forming in a terahertz dance around peptides and whole proteins. Origins-of-life experiments (Miller-Urey, Butlerow, Oró) are briefly reviewed, with a primer on how single critical events that are highly improbable – given sufficient trials over time – become almost inevitable. The common origins of nucleic acid, protein, and lipid precursors arising from the Kiliani-Fischer homologation chemistry requires periodic delivery of cyanosulfidic reagents in a primordial soup, with just a dash of ultraviolet light, sketching comparisons with deep-sea hydrothermal vents on Earth and brines for extremophilic life on the celestial bodies Ceres, Europa, and Enceladus. Supercriticality and collective electrodynamic effects serve as organizing speedups in the aqueous milieu. The lecture concludes with a broad picture of the chemistry and physics of photosynthesis, aerobic respiration, and the seeding of life from aromatic heterocycles in the interstellar media.

Relevant papers by the speaker

Kurian P. Computational capacity of life in relation to the universe. *Sci. Adv*. 2025;11(13). DOI: **doi.org/10.1126/sciadv.adt4623**.

Azizi K, Gori M, Morzan U, Hassanali A, Kurian P. Examining the origins of observed terahertz modes from an optically pumped atomistic model protein in aqueous solution. *PNAS Nexus*. 2023;2(8):1-13. DOI: **doi.org/10.1093/pnasnexus/pgad257**.

Kurian P, Capolupo A, Craddock TJA, Vitiello G. Water-mediated correlations in DNA-enzyme interactions. *Physics Letters A*. 2018;382(1):33-43. DOI: **doi.org/10.1016/j.physleta.2017.10.038**.

For more about Philip’s research see Google Scholar here, or the Quantum Biology Laboratory here.

The physics of water: charge, membranes and interactions with light

Dr Ali Hassanali

The International Center for Theoretical Physics, Trieste

View the video recording **here**.

This lecture looks closely at the behaviour of water at different interfaces and in different conditions. Dr Ali Hassanali builds on his research into the use of soap bubbles for artificial photosynthesis and the interesting properties - big electric fields, ordered water - associated with these 'model membranes'. How might a microscopic understanding of the physics of this simpler interfacial system give insight into how water behaves around the charged membranes - mitochondrial and cellular membranes for instance - that are so integral to biological functioning? Ali also discusses the importance and open questions regarding light-matter interactions where water plays a crucial role. Throughout his talk he touches upon the apparent contentious issues and claims that the scientific study of water elicits.

Relevant papers by the speaker

Flór M, Wilkins DM, de la Puente M, Laage D, Cassone G, Hassanali A, Roke, S. Dissecting the hydrogen bond network of water: Charge transfer and nuclear quantum effects. *Science.* 2024;386(6726). DOI: **doi.org/10.1126/science.ads4369**.

Gong K, Nandy A, Song Z, Li QS, Hassanali A, Cassone G, Banerjee S, Xie J. Revisiting the Enhanced Chemical Reactivity in Water Microdroplets: The Case of a Diels–Alder Reaction. *Journal of the American Chemical Society*. 2024;146(46):31585-31596. DOI: **doi.org/10.1021/jacs.4c09400**.

Poli E, Jong KH, Hassanali A. Charge transfer as a ubiquitous mechanism in determining the negative charge at hydrophobic interfaces. *Nature communications*. 2020;11(901). DOI: **doi.org/10.1038/s41467-020-14659-5**.

Bellissent-Funel MC, Hassanali A, et al. Water determines the structure and dynamics of proteins. *Chemical reviews*. 2016;11 (13):7673-7697. **doi.org/10.1021/acs.chemrev.5b00664**.

For more about Ali's research see Google Scholar here

Quantum Effects of Water Associated with Proteins - The Importance of Order

Dr Nathan Babcock

Howard University

View the video recording **here**.

This lecture will provide a concise overview of quantum effects in water associated with proteins, with special focus on the importance of order in biological water. Beginning with Einstein's seminal 1905 study of the quantum mechanical nature of “warm, wet, noisy” matter, we will consider the fundamental role of quantum physics in determining the structure and chemical properties of liquid water. The importance of structural order in water between and around proteins will be examined in the context of biological electron transfer, proton tunneling, enzyme catalysis, van der Waals forces in DNA and intrinsically disordered proteins, and ATP synthesis. The role of the water network as a mediator of quantum mechanical effects in biochemical reactions is proposed with implications for applications in medicine and biotechnology.

Relevant papers by the speaker

De la Lande A, Babcock NS, Řezáč J, Lévy B, Sanders BC, Salahub DR. Quantum effects in biological electron transfer. *Physical Chemistry Chemical Physics*. 2012;14(17):5902-18. DOI: **doi.org/10.1039/C2CP21823B**.

De la Lande A, Babcock NS, Řezáč J, Sanders BC, Salahub DR. Surface residues dynamically organize water bridges to enhance electron transfer between proteins. *Proceedings of the National Academy of Sciences.* 2010;107(26):11799-11804. DOI: **doi.org/10.1073/pnas.0914457107**.

For more about Nathan’s research see Google Scholar here.

Origins of life: water, lights, action

Dr Robert Fosbury

UCL and Emeritus Astronomer at the European Southern Observatory (ESO)

View the video recording **here**.

In this introduction to Alistair Nunn's presentation, I suggest that the sunlight reaching the Earth's surface is both qualitatively and quantitatively matched to the energy requirements for life on the planet in a coupling that is more intimate than has been appreciated. Due to the properties of the atmospheres in Sun-like and cooler stars, the emission measured in photon rate per unit energy, peaks at a photon energy of 0.75 eV. This is very close to the metabolic action potential of all of life which has a mean value of 0.66 eV. The absolute value of the photon flux would provide significant energy to catalyse the electron transport chains throughout much of the biosphere. I suggest that water could be an important chromophore to mediate the photon-biomolecular interaction.

Relevant papers by the speaker

Fosbury RAE, Jeffery G. Reindeer eyes seasonally adapt to ozone-blue Arctic twilight by tuning a photonic tapetum lucidum. *Proceedings of the Royal Society B*. 2022;289(1977):1-9. DOI: **doi.org/10.1098/rspb.2022.1002**.

Kam JH, Hogg C, Fosbury R, Shinhmar H, Jeffery G. Mitochondria are specifically vulnerable to 420nm light in drosophila which undermines their function and is associated with reduced fly mobility. *Plos one*. 2021;16(9):1-13. DOI: **doi.org/10.1371/journal.pone.0257149**.

For more about Robert's research see Google Scholar here.

Origins of life: water, lights, action; Goldilocks and the light spectrum

Professor Alistair Nunn

The Guy Foundation and University of Westminster

View the video recording **here**.

There is still no consensus of the origins of life, although several theories have been proposed, ranging from deep sea thermal vents to ponds that have dry/wet cycles leading to polymerisation and RNA based theories. However, the chemistry of the galaxy can produce most of the carbon-based molecules that led to life, while water is an essential component of life and stellar and planetary evolution. Key in this process has been a supply of energy, in particular, heat and light. Extant life is electrical due to its reliance on a flow of electrons leading to proton gradients, and is modulated by light, while producing its own photons. If combined with the observation that most of its essential compounds are chromophoric, it seems that both electrical fields and photons are important in homeostasis. Critically, life is a far from equilibrium self-organising dissipating structure, indicating that adaptive thermodynamics and quantum mechanics can explain why it came into being, which is reflected in its apparent wastefulness due to uncoupling and futile cycling. The seeds of this thinking came about in the late 19th century when the concept of a “morphogenetic field” was conceived to explain why creatures were shaped the way they were, which led to Alexander Gurwitsch discovering “mitogenetic rays” emanating from onion roots, laying the foundation for bioelectromagnetics and photobiology, linked through quantum mechanics, and the concept of “fields of life”. These ideas are being used to explain why red/infrared (IR) light seems to be medically beneficial. If this is combined with the observation that water not only has some interesting quantum properties, as it is polar, but is also a highly efficient absorber of far ultraviolet (UV), and red and IR, while being transparent to the visible spectrum, it begins to hint at a possible location for where life may have started. Water is the dominant metabolite in biochemistry and its viscosity can be altered by red and IR, as well as electric fields. In this talk I suggest that this all points towards the alkaline thermal vent, or something similar near to the sea surface, such as a kind of vent found in Eyjafjordur today, as good candidates for where life started, as these vents not only have a crystalline cellular structure, but also generate photons, particularly in the infrared, generate electric fields, and were likely bathed in a mix of prebiotic carbon molecules and other essential metal ions. As near UV can penetrate several meters into water, while IR cannot, and the early earth was probably exposed to very high levels of UV, this does hint that the surface could have been too toxic for life to start, whereas thermal vents could have existed in a

Goldilocks zone. This would explain why life relies today on bioelectric fields, a proton gradient, and we suggest, some kind of photonic homeostatic system that we may be able to tune, particularly in the mitochondrion

Relevant papers by the speaker

Nunn AVW, Guy GW, Bell JD. Bioelectric fields at the beginnings of life. *Bioelectricity*. 2022;4(4):237-247. DOI: **doi.org/10.1089/bioe.2022.0012**.

Nunn AVW, Guy GW, Botchway SW, Bell JD. From sunscreens to medicines: Can a dissipation hypothesis explain the beneficial aspects of many plant compounds? *Phytotherapy Research*. 2020;34(8):1868-1888. DOI: **doi.org/10.1002/ptr.6654**.

For more about Alistair's research see Google Scholar here.

Insights and implications: water in biology

Professor Wayne Frasch

Arizona State University

View the video recording **here**.

Water is fundamental to terrestrial life's biochemical processes, from the origin of life to complex energy conversion mechanisms such as photosynthesis and oxidative phosphorylation. In contrast, the possibility of life in high-pressure, high-temperature environments – such as gas giants – suggests that entirely different molecular systems might operate in non-aqueous conditions. Water's unique properties enable the maintenance of electrochemical gradients across thin membranes and regulate protein folding, stability, function, and order through hydration shells and ionic interactions. The role of water extends to highly selective channels like aquaporins, which facilitate single-file water transport while excluding ions. Water is also important in electron transfer processes in photosynthetic reaction centers, where its dynamics influence reorganisation energies and reaction rates consistent with Marcus theory. This talk focuses on the oxygen-evolving complex of photosystem II, especially its dependency on chloride ions to prevent the formation of damaging reactive oxygen species. The manganese-calcium cluster's role in storing oxidising equivalents and the four sequential single photon-driven oxidations of the manganese-calcium cluster that then catalyzes the oxidation of water is the primary source of oxygen production on Earth. The talk raises questions about the behaviour of water under nanoconfinement, which may alter its dielectric properties and modulate biological processes like ATP synthesis. The discussion describes detailed single-molecule studies of ATP synthase, which suggest proton transfer via coupled input-output channels and a Grotthuss-like mechanism involving structured water chains, driving discrete rotational steps that are critical for energy transduction. Recent structural findings confirm these water channels and a periplasmic proton antenna that enhances proton uptake. Finally, the impact of confined water properties and infrared light on proton mobility highlights new frontiers in understanding bioenergetics and the therapeutic application of light.

Relevant papers by the speaker

Fine PL, Frasch WD. The oxygen-evolving complex requires chloride to prevent hydrogen peroxide formation. *Biochemistry*. 1992;31(48):12204-10. DOI: **doi.org/10.1021/bi00163a033**.

Frasch WD, Bukhari ZA, Yanagisawa S. F_1F_O ATP synthase molecular motor mechanisms. *Front Microbiol.* 2022;13. DOI: **doi.org/10.3389/fmicb.2022.965620**.

For more about Wayne's research see Google Scholar here.

Closing Note

Professor Geoffrey Guy

Founder and Chairman, The Guy Foundation

The Guy Foundation 2025 Spring Series ended with a fascinating interdisciplinary discussion exploring the foundational role of water in biological function, with a strong focus on how its behaviour under different physical conditions – such as confinement, interfacial environments, and electromagnetic fields – modulates life at the molecular level. The implications for medicine, pharmacology, and space biology were also raised.

In this discussion a number of themes emerged, one of which was the influence of interfacial or confined water on proton dynamics and biological regulation. It was suggested that structured water at interfaces might mimic confinement and influence proton mobility – which is key to energy transduction and signalling – by leveraging the amphiphilic nature of protons and slowing their diffusion at interfaces. This could have implications for how biological systems trap or regulate protons, including in protein protonation states and enzyme activity.

The role that water plays in proton transport was expanded on in a discussion of quantum tunnelling in the context of water, proteins, and water-protein interactions. Judith Klinman's foundational work on proton tunnelling and protein "quakes" in enzyme rate speed-ups, was revisited from the point of view of structured versus bulk water, as well as the possibility of "water wires" and tunnelling in water itself. The toxicity of heavy water at certain thresholds suggests a biological sensitivity to even minor vibrational changes as well as the possibility of spin effects.

Water's facilitation of collective electromagnetic effects also stimulated a great deal of interest, with a discussion of aromatic biomolecular networks and their generation of radiative dipole modes and long-range electrodynamic effects. The synergistic effects of electromagnetic radiation – light – and water were the subject of vigorous debate, in particular the role of infrared light in modulating water's properties, wavelength-specific effects, and photon trapping in cellular nanostructures.

In the context of the Foundation's research interests, two threads emerged: space health and the future of medicine. The first of these addressed the implication of water in the origins of life on Earth and what this means for space biology. It was suggested that because different wavelengths of light penetrate water to varying depths in water, early life may have evolved in response to optimal photonic environments. Indeed, weak but well-regulated UV light in dark environments could have

stimulated non-destructive biological outcomes and energy down-conversion by appropriate biomolecules, implying environmental tuning for energy harvesting and harnessing across the spectrum. Furthermore, the unique and indispensable role that water plays in Earth's biology, suggests alternative biochemistries in extraterrestrial environments. For example, the gravitational context of a planet (such as its size and density) directly influences whether subsurface environments can maintain conditions suitable for life, such as warm oceans or hydrothermal vents.

Secondly, given the extensive effort invested in the development of worthwhile medicines, the omission of water from key scientific discussions appears to be a profound oversight. Chemists and pharmaceutical scientists have explored drug synthesis, ligand-receptor interactions, and protein-protein mechanisms and yet none have acknowledged the active role of water in these processes. What this series has illustrated is that we may be on the frontier of a wholly new way to think about “hydro-therapy”.

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