THE GUY FOUNDATION

Quantum mitochondria: energy, information and implications for health and disease

Abstract proceedings of the 6th Guy Foundation Symposium on Quantum Biology and Bioenergetics, Autumn 2022

Driving innovation in medicine through quantum biology

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QUANTUM MITOCHONDRIA:

ENERGY, INFORMATION AND IMPLICATIONS FOR HEALTH AND DISEASE

Introduction to the 6th Guy Foundation Symposium

Betony Adams & Alistair Nunn

The Guy Foundation online symposia have explored topics ranging from the fundamental concepts of quantum mechanics to their application in new therapeutics. A consistent theme has been the importance of mitochondria and with this in mind, mitochondria were the focus for the 2022 Autumn Series; how they respond to different conditions, how they have optimised their function with respect to Earth's specific magnetic and gravitational field and how this has implications for health and disease. A closer look at mitochondria also widens the scope of quantum biology. Many of the topics of interest in quantum biology – energy and charge transfer between chromophores, the control of radical species – are central to the function of mitochondria. There is also growing evidence that mitochondrial dysfunction is at the heart a number of different diseases. As such, the mitochondrion offers a promising site for advancing our understanding of how quantum effects play a role in biological systems, and how this might be leveraged into new therapeutics.

Mitochondria are often simply described as "power stations" of the cell, and occasionally, as potentially disruptive sources of reactive oxygen species (ROS). This truth, however, is more complex. Modern eukaryotic cells are thought to have evolved from an Archean and a bacterium, with the latter incorporated as the mitochondrion. This implies that mitochondria are involved in almost every aspect of the cell. For example, they are pivotal in inflammation and immunity, the generation of the building blocks of cells, modulation of redox, controlling cell death and survival, as well ion homeostasis and energy production. They are also integral to sensing the cellular environment. Their central metabolic pathway, the Krebs cycle, can be traced almost all the way back to the origins of life and is intimately coupled to perhaps an even older process: the electron

transport chain and the proton gradient. What is perhaps also less widely appreciated is that they may well be reliant on fundamental quantum processes, such as tunnelling and spin-dependent chemistry, and that they generate strong electric fields. While not discussed explicitly discussed in this series, they can also generate, and react to, photons. This thus suggests that coherence could play a role in homeostasis. From this perspective, we should perhaps consider the concept of the "quantum mitochondrion" as the next step in developing a deeper understanding of biology.

On a more immediately practical level, mitochondria may, as was suggested in one of the presentations, act as a protective mechanism against pathogens. Disruption of the balance of these different mitochondrial functions – energy production, pathogen control – thus offers a way to explain features of diseases such as chronic fatigue syndrome, myalgic encephalomyelitis and, more recently, long COVID. In some cells, for instance, mitochondria may operate in a biosynthetic mode, while in others, they generate ATP; even within a single cell, individual mitochondria may be completing different tasks. This is clearly shown by the Krebs cycle, which can operate in several different modes, suggesting it is more like a roundabout than a cycle. The problem is then one of capacity and functionality. If the mitochondrial system is sub-optimal to begin with, it may not be robust enough to help fight off pathogens, resulting in an inflammatory feedback cycle. This is made worse because the pathogens themselves can reprogramme mitochondrial function for their own ends.

Mitochondrial energetics are also inextricably coupled to the production of a proton gradient or membrane potential, which drives the molecular machinery of ATPases to produce adenosine triphosphate (ATP). ATPases are a widely conserved biological hardware essential to mitochondria, but also to the wider context of membrane potential dependent morphology. ATPases, for example, modulate the development of left-right symmetry. Mitochondria are also a major source of reactive oxygen species (ROS), which are important signalling molecules in biological systems but are also involved in inflammatory processes and cellular damage. The manipulation of ROS by magnetic fields is a growing topic of interest in quantum biology, where the underlying spin states of reaction intermediates dictate chemical and, potentially, biological outcomes. The use of specific magnetic fields to alter stem cell growth has been demonstrated with respect to planaria, with possible application to regenerative medicine as well as cancer research.

Mitochondria, as demonstrated by the various presentations in the Autumn Series, play a profound role in biological systems and how these systems respond to their environment. This response must necessarily balance metabolic processes with adaptive and protective purposes: against pathogens, but also against changes to the physical environment – the external magnetic or gravitational fields – in which mitochondria evolved. Mitochondria are tuned to this environment, a fact that was made abundantly clear in the final session of the Autumn Series, which documented the wealth of evidence demonstrating mitochondrial changes due to space travel, and in particular microgravity conditions. One of the key problems, certainly for human health, is that modern society has removed many factors which stimulate mitochondrial health, such as the need to exercise, or fast; underlying this is the concept of adaptation by hormesis. It is thus likely that one of the main causes of mitochondrial dysfunction in astronauts is the removal of one of the most powerful hormetic stimuli, gravity. Advancing our knowledge of the exact mechanisms and parameters of the tuning of mitochondria to their environment will undoubtedly advance our understanding of health and disease.

Introduction to The Guy Foundation

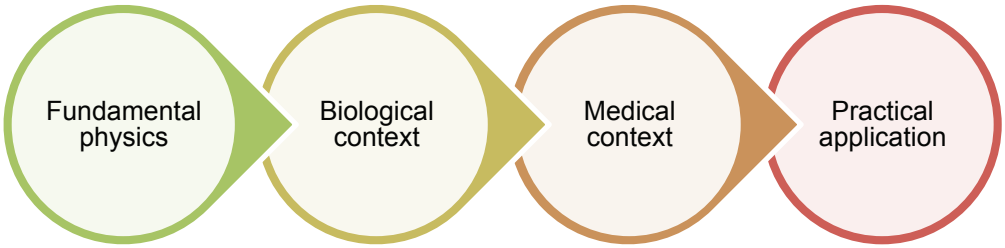
Professor Geoffrey Guy

Founder and Chairman, The Guy Foundation

The Guy Foundation aims to support and promote 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 life to get going, but also enabled it to grow in complexity by amplifying these effects both in space and time. All living systems depend on iron-sulphur compounds that display interesting tunnelling properties, which could be enhanced by the addition of proteins and chromophoric molecules. These molecules were all created by well understood geochemical/interstellar chemical processes long before life began, which coupled with established thermodynamic mathematical principles involving self-organisation of dissipative structures in energy gradients, do provide the basis of a starting point for life. In short, if significant quantum effects are part of life, the failure to maintain this state probably plays a role in disease and thus, the ageing process, and, of course, medicine.

The pioneers of thermodynamics and quantum physics, and – over the years – scientists, embracing many different disciplines, have discussed the possibility that biology could be using significant quantum effects. Some, such as Roger Penrose, have even gone as far as suggesting it could explain consciousness itself, which, even today in the 21st century, is still far from being understood. In fact, with time, despite the 20th century optimism that by the 21st century mankind would have found cures for cancer and many other diseases, and possibly even for ageing itself, a deeper understanding of life seems to be still out of reach. It could be even further away as emerging global obesity appears to be *shortening* both a healthy and absolute life expectancy, which is resulting in spiralling health care costs across the planet. Despite mankind's emerging technical mastery of nature, we still have a very long way to go in terms of truly understanding it.

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 cross-section of scientists invited to give presentations. 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 new diagnostics and therapeutics.

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 in biology in health and disease. With an emphasis on building a research community to further investigate these interests, The Guy Foundation operates in a spirit of collaboration rather than straightforward grant funding, to advance the course of useful knowledge towards the mainstream and bring it to the attention of more conventional funders. We aim to do this in various ways. For instance, by curating a programme of scientific meetings and publications that incorporates the diverse aspects of the field and facilitates engagement from scientists across relevant disciplines; as well as by identifying what we see as research priorities and building a network of interested scientists through the funding of collaborative projects to accelerate relevant high-quality scientific research.

Professor Geoffrey Guy MB BS, LRCP MRCS, LMSSA, DipPharmMed, BSc, DSc
Founder and Chairman of the Board of Trustees, The Guy Foundation

Abstract Proceedings

These are abstracts of a series of talks, hosted by the Foundation, that were given online to an invited audience during the autumn of 2022.

They have been written by the presenters and have not been formally peer-reviewed. We hope you enjoy them; video recordings of the full lectures are available on the Foundation's website **www.theguyfoundation.org**.

Long, long COVID: a brief history of time, life and evolution

Professor Alistair Nunn

Visiting Professor, Research Centre for Optimal Health, University of Westminster and Director of Science, The Guy Foundation

Long COVID is a post viral syndrome, which can last two years or more and affects 10-15% of those infected. Physical symptoms include exercise intolerance, brain fog, loss of smell, tiredness, joint ache, headaches, breathlessness and occasionally, problems with eyes and kidneys, as well as other organs, including the heart. Physiologically, it is associated with clotting, epigenetic, metabolic and redox imbalances, chronic inflammation and mitochondrial dysfunction. It shares many of the characteristics of an accelerated ageing syndrome and seems to preferentially afflict poor lifestyle populations and older individuals, as well as those with co-morbidities. It also correlates with initial severity and can occur following break-through infections following vaccination. The precise cause is unknown, but may include viral persistence, reactivation of other viruses, autoimmunity, chronic inflammation due to tissue damage, as well as clotting problems. We have suggested that a key predisposing factor, both to the initial severity and to long COVID, is reduced metabolic flexibility due to sub-optimal mitochondrial function following a lack of hormesis associated with a poor lifestyle. For example, reduced exercise, fasting, temperature extremes and phenolic compounds; all of which stimulate an adaptive upregulation of mitochondrial function and probably existed throughout evolution until the development of technology. The underlying biochemistry can be traced back to the origins of life and an ancient metabolic pathway called the Krebs cycle, which may have come into being in a thermal vent where a flow of hydrogen into carbon dioxide containing sea water created a strong energy gradient. These conditions, perhaps coupled to the existence of prebiotic cyclic chemicals and iron compounds, and the electric fields generated by the movement of ions, led to a self-organising far from equilibrium structure that obeyed the laws of thermodynamics that dissipated energy from the proton gradient, and perhaps, embraced quantum effects to function. In effect, the dissipative process generated compounds that form life, and in time, this life evolved to use some of these compounds to operate in reverse (effectively “eating” these compounds to generate its own proton gradient by extracting energy via the flow of electrons). Today, this process is largely undertaken in the mitochondrion, but coupled to a process called glycolysis than can operate without oxygen for a period to generate energy. However, the Krebs cycle can still run in the original direction to generate compounds used to build life; this process is

also utilised during inflammation, which is why it is so tightly linked to hypoxia as life originally evolved in a world with little or no oxygen, so used other electron acceptors until photosynthesis evolved and oxygen became plentiful. The SARs-CoV-2 virus can metabolically reprogramme its host to help it avoid the immune system and generate metabolic precursors. The problem is that this reprogramming is very similar to what happens in inflammation, and because the mitochondrion is central to most pathways, if the host's mitochondrial reserve is already compromised, it is possible that the virus can "tip" its host into chronic inflammatory cycle by overloading mitochondrial function. This would suggest that careful use of hormetic stimuli may be needed to restore optimal mitochondrial health.

Nunn, Alistair V. W., Geoffrey W. Guy, Wolfgang Brysch, and Jimmy D. Bell. 2022.
"Understanding Long COVID; Mitochondrial Health and Adaptation—Old Pathways, New Problems"
Biomedicines **10(12)**: 3113. https://doi.org/10.3390/biomedicines10123113

Mitochondrial dysfunction: relevance for Chronic Fatigue Syndrome and long COVID

Professor Karl Morten

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Mitochondrial therapeutics is an emerging field in medicine with growing interest from the pharmaceutical sector. Many well-known conditions, including Alzheimer's/Parkinson's disease, multiple sclerosis and diabetes show mitochondrial dysfunction, which has yet to be fully explored as a potential therapeutic target. Other less well-defined chronic conditions, including Myalgic Encephalomyelitis/Chronic Fatigue Syndrome (ME/CFS), Long Covid and Gulf War Syndrome (GWS), also show elements of mitochondrial dysfunction. ME/CFS is the best studied with evidence of energy dysregulation observed in peripheral blood mononuclear cells and a systemic effect with reduced levels of amino acids in plasma possibly linked to altered fuel use. Although it is unclear if mitochondrial dysfunction is directly involved in ME/CFS, there appears to be an abnormal energy balance. Patient symptoms will worsen if they expend too much energy during physical exertion or by undertaking cognitive tasks. Post exertional malaise (PEM) in ME/CFS and Long Covid is a characteristic feature, which differentiates the conditions from clinical depression, which can also associate with severe fatigue.

Mitochondria are the primary generators of aerobic energy production in eukaryotic tissues, but also have roles in infection, being a key component of the innate immune response to bacterial and viral pathogens, while also dealing with intracellular pathogens. How cells balance the energy and metabolic needs of the cell with other mitochondrial pathogen-associated roles is likely important in the chronic diseases outlined earlier. Most of the conditions outlined above are associated with pathogens at some stage of the disease process. Mammalian tissues differ in their mitochondrial content. Heart has the highest number of mitochondria relative to its volume at 37%, while the brain has very few at 5%. With the brain being the largest consumer of oxygen and glucose in the body: how does the brain generate enough energy to meet its high ATP requirement with so few mitochondria? In this presentation, we speculate that in cells with a high aerobic ATP production need, other membrane systems containing mitochondrial components are the primary generators of

aerobic ATP. These membrane systems include myelin in neurons, the membranes of the outer segment of rod cells in the retina and the endoplasmic reticulum in antibody producing plasmablast cells. All of these cells have a very large aerobic energy need but appear to have insufficient mitochondria. This lack of mitochondria may also impact on the ability of these cells to deal with intracellular pathogens. Both mitochondrial DNA shedding, to trigger an innate immune response, and engulfment of intracellular pathogens both play a role in how we deal with pathogens. With the microbiome now extending beyond the gut and into our cells and tissues, how we work with these invaders is an important factor in our health and well-being. With mitochondria having a significant pathogen defence role, cells lacking mitochondria in the long-term may be more vulnerable to the establishment of chronic conditions, with genetic and physiological differences in individuals making some more susceptible than others.

From nanotech to living sensors: unraveling the spin physics of biosensing at the nanoscale

Professor Clarice Aiello

Quantum Biology Tech Lab (QuBiT), UCLA

Substantial in vitro and physiological experimental results suggest that similar coherent spin physics might underlie phenomena as varied as the biosensing of magnetic fields in animal navigation and the magnetosensitivity of metabolic reactions related to oxidative stress in cells. If this is correct, organisms might behave, for a short time, as “living quantum sensors” and might be studied and controlled using quantum sensing techniques developed for technological sensors. I will outline our approach towards performing coherent quantum measurements and control on proteins, cells and organisms in order to understand how they interact with their environment, and how physiology is regulated by such interactions. Can coherent spin physics be established – or refuted! – to account for physiologically relevant biosensing phenomena, and be manipulated to technological and therapeutic advantage?

Radical oxygen species, weak magnetic fields, and tissue growth

Professor Wendy Beane

Department of Biological Sciences, Western Michigan University

Reactive oxygen species (ROS) signaling is complex and nuanced, with ROS arising from mitochondrial, intercellular, and extracellular sources. High levels of ROS can lead to cell death, while too little ROS is equally harmful by interfering with homeostasis and host defenses. In between these extremes, ROS have been recognized as important components of cell signaling controlling cell behaviors and tissue growth in development, regeneration, and cancer. In addition, careful modulation of ROS is known to regulate stem cell states, promoting quiescence, division, or differentiation at different threshold levels. Therefore, identifying non-invasive methods to manipulate ROS levels *in vivo* could radically change our current therapeutic protocols. Recent advances have highlighted the use of weak magnetic fields (WMFs, <1 mT) as one promising approach. Using the planarian model system, our group is investigating the ability of WMFs to modulate stem cell activity during regeneration. Our data reveal that WMF exposure following injury, in a field strength-dependent manner, can either increase (500 μT) or decrease (200 μT): ROS accumulation, ROS-mediated Hsp70 gene expression, adult stem cell proliferation, and blastema (new tissue) growth [1]. These findings reveal that WMFs can be used for directed manipulation of stem cell activities in predictable ways for both loss and gain of function during regenerative growth. Furthermore, most recently we have examined two of the most common ROS signaling effectors, hydrogen peroxide and superoxide, to begin the identification and elucidation of the specific molecular targets by which WMFs affect tissue growth. Our results suggest that the cellular effects of WMF exposure are highly dependent on altered levels of the superoxide radical at the wound site. Altogether, these data suggest quantum approaches to controlling stem cells are an important emerging research area.

Nunn [1] Van Huizen AV, Morton JM, Kinsey LJ, Von Kannon DG, Saad MA, Birkholz TR, Czajka JM, Cyrus J, Barnes FS, Beane WS. (2019) Weak magnetic fields alter stem cell–mediated growth. *Science Advances*, Jan 30;5(1): eaau7201. DOI: 10.1126/sciadv.aau7201

Bioelectricity: how cell-level physiology scales up into anatomy and cognition

Professor Mike Levin

Allen Discovery Centre, Tufts University

Biology is fundamentally built on a multi-scale competency architecture: every level of organization is able to solve specific problems (physiological, transcriptional, morphological, behavioral) with various degrees of intelligence. One of the most interesting aspects, for evolutionary biology and biomedicine, is the ability of information to cross levels. How does metabolic activity at the subcellular level scale up to order on the tissue, organ, and whole-body levels, eventually becoming brain-directed behavior? In this talk, I will describe developmental bioelectricity as a kind of cognitive glue: a set of information-processing mechanisms that enables scale-up of cellular activity into higher-order functions such as morphogenesis and eventually, brain-mediated cognition. Specifically, I will focus on the V-ATPase ion pump, describing two specific roles: 1) driving appendage regeneration, and 2) scaling up left-right asymmetry information from the directional chirality of the subcellular cytoskeleton into positional information of the asymmetric heart and viscera. Numerous powerful applications will become possible when we master the scaling of physiological homeostatic loops into higher order information structures that regulate health and disease.

Interconversion of transmembrane ion gradients and membrane potentials with ATP concentration catalyzed by the F, A and V-type superfamily

Professor Wayne Frasch

Biomedicine and Biotechnology faculty group, Arizona State University

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Life is fueled by ATP primarily synthesized by the F_1F_O ATP synthase molecular motor. Oxidation of metabolites consumed by an organism are initially converted to a nonequilibrium transmembrane proton gradient that also generates a membrane potential. These are used by the F-type ATP synthase to drive rotation of a turbine in the membrane-embedded F_O that is attached to the drive shaft of F_1, which produces three ATP with each rotation. Each c-subunit in the turbine receives a proton that is delivered across the membrane after rotation. Our recent data show that Grotthuss-type proton translocation drives 11° rotation steps of the turbine that alternate with rotation steps driven by electrostatic attraction between the turbine and the stator. The turbine varies from a c_8-ring (mammals) to a c_{15}-ring (cyanobacteria) such that the energetic cost of making three ATPs in cyanobacteria (15 protons) is nearly twice that in mammals (8 protons). The energetic contributions of pH gradient and membrane potential for ATP synthesis also vary across the tree of life, although to date. Under some conditions F_1F_O can hydrolyze ATP to pump protons in the opposite direction. F-type ATP synthases are part of a superfamily of rotary motors that includes A_1A_O ATP synthases (in Archaea bacteria) and V_1V_O ATPases (vacuolar). These share F-type core structural aspects but vary in stator and regulatory components. V-types are only capable of ATPase-driven proton pumping across ER, Golgi, lysosomes and plasma membranes, which acidifies these organelles and creates a membrane potential that is used to power diverse cellular processes. V_O stator isoforms target specific organelles and vary the motor efficiency to maintain a unique pH. V-type ATPases are regulated by cellular metabolism that reversibly dissociates V_1 from V_O.

Mitochondrial dysregulation as the universal driver of space flight across all species

Professor Afshin Beheshti

KBR at NASA Ames Research Center

Determining the biological impact of spaceflight through novel approaches is essential to reduce the health risks to astronauts for long-term space missions. The current established health risks due to spaceflight are only reflecting known symptomatic and physiologic responses and do not reflect early onset of other potential diseases. There are many unknown variables which still need to be identified to fully understand the health impacts due to the environmental factors in space. One method to uncover potential novel biological mechanisms responsible for health risks in astronauts is by utilizing NASA's GeneLab platform (genelab.nasa.gov). GeneLab is a public repository that hosts multiple omics datasets generated from space biology experiments that include experiments flown in space, simulated cosmic radiation experiments, and simulated microgravity experiments. Utilizing GeneLab, a comprehensive multi-omics approach was implemented correlating transcriptomics, proteomics, metabolomics, and methylation analysis. We found that cells have stronger overall biological response than the tissues to spaceflight, with mitochondrial activity and innate immunity pathways being heavily impacted. NASA Twin Study results are consistent with a specific alteration in mitochondrial ATP production. In addition, when expanding on this initial finding with other organisms (i.e. C. elegans, plants, etc.) we observe similar mitochondrial changes occurring during spaceflight. Our results indicate that the space environment can directly induce mitochondrial damage, with mitochondrial dysfunctions being a cause for chronic inflammation and both being involved in the development of metabolic disorders that cause changes in lipid metabolism. We also found biological changes occurring during spaceflight with cell cycle, circadian rhythm and olfactory activity pathways, many of which can also influence and be influenced by alterations to mitochondrial activity. In addition, from our earlier work, we demonstrated a circulating microRNA (miRNA) signature that is present and involved with the general increased health risks during spaceflight that impacts mitochondrial function directly. From this work we demonstrated that this miRNA signature impacted the overall biology and health with both the microgravity and space radiation components of the space environment. We showed that this miRNA signature can be an optimal biomarker for health risk and also has potential to be utilized as a countermeasure to

mitigate the damage caused by the space environment by utilizing a human 3D microvascular tissue model. By applying a novel self-delivery system to target 3 miRNAs (i.e. antagomirs) from our spaceflight miRNA signature impacting cardiovascular health risks, we were able to completely mitigate damage caused by exposure to simulated Galactic Cosmic Ray (GCR) irradiation. Here we further expand on the countermeasure experiments to uncover the specific novel biology involved with this countermeasure and *in vivo* experiments that demonstrates that these antagomirs rescue damage caused to certain organs due to both microgravity and space radiation. Specifically, the miRNAs rescued damage to the heart, immune suppression, and improved mitochondrial function that occurs during spaceflight in addition to other key biology. In addition, we have also observed with the 3D microvascular tissue model improved DNA double strand break repair machinery which can also contribute to improved recovery and protection against damage caused by space radiation. This work expands on our previous work and further uncovers how a potential minimally invasive countermeasure can be used to mitigate space environment effects and that mitochondrial dysfunction is a key driver in biological response to spaceflight and potentially can lead to health risks.

Mitochondrial physics: is it quantum

Professor Doug Wallace

Director, Center for Mitochondrial and Epigenomic Medicine at The Children's Hospital of Philadelphia Research Institute

We have discovered that the mitochondrial inner membrane infoldings (cristae) are closed at the intermembrane interface by Opa1 and MICOS. This results in the mitochondrial inner membrane electron transport chain (ETC) pumping protons into the small volume cristae lumens, presumably resulting in high charge densities. The ATP synthases are arrayed along the cristae edges thus maximizing proton drive for ATP synthesis. The cristae in adjacent heart mitochondria are aligned which could result from electrostatic interactions. Uncontrolled ETC proton pumping could result in disruptive intra-lumen charge density. This is countered by the mitochondrial inner membrane adenine nucleotide translocators (ANTs) which are bifunctional, exchanging ATP and ADP across the inner membrane but also acting as a voltage-sensitive proton channels, with the channel opening at ~180 mv. Hence, the ANTs act as proton pressure release valves resulting in oscillating membrane potential. These mitochondrial oscillations could generate electromagnetic fields which could emanate from the brain and heart, perhaps generating the clinical EEGs and EKGs. In autism, magnetoencephalographs (MEGs) are modified and autism has been linked to mitochondrial dysfunction by associating mitochondrial DNA (mtDNA) variation with autism risk. A mitochondrial etiology of autism has been established by our mouse model, harboring a mtDNA missense mutation in the ETC complex I *MT-ND6* gene. This mouse manifests the behavioral features of autism and has an altered EEG. Thus, we have linked mitochondrial dysfunction to autism and demonstrated that mitochondrial alterations determine the frequencies of the EEG. Mitochondrial electromagnetic oscillations could impinge on the electron spin states in ETC flavins and perhaps influence the nuclear spin states of phosphates in mitochondrial Posner molecules. If mitochondrial oscillation frequencies are coherent across adjacent mitochondria within cells, such fields might permit inter-cellular and inter-organ signaling. This could link mitochondrial function to neuropsychiatric disorders and perhaps to cognition and the health benefits of meditation, Tai-Chi, and acupuncture.

Closing Note

Professor Geoffrey Guy

Founder and Chairman, The Guy Foundation

If mitochondria, as the Autumn Series has demonstrated, are central to so many important biological processes, and implicated in a number of different diseases, why is it that they remain peripheral to conventional medical approaches. Doug Wallace has spent decades investigating mitochondria, from the point of view of genetics to, more recently, that of quantum biology. Genes offer invaluable insights into many aspects of mitochondrial biology, most notably the mapping of migrations based on maternal mitochondrial DNA. However, it is becoming clearer that a full understanding of mitochondria cannot neglect electromagnetic effects and how these might be explained by quantum physics. In his presentation at the concluding session of the Autumn Series, Doug made the potentially controversial observation that all diseases might be traced back to dysfunctional mitochondria. This entails a shift towards recognising the importance of bioenergetics, instead of centralising anatomy as foundational to understanding disease. A more moderate statement might be that the larger scale anatomical structure of biological systems is inseparable from the elements that constitute it. The collective properties of cells are informed by their underlying constituents, bound by bioelectric or bioenergetic glue. Large scale morphological design, for instance, is dependent on the molecular hardware of something like ATPase, the functioning of which is also coupled to metabolic concerns.

Why then, is there still a persistent reluctance to widen the paradigm of conventional medicine, and what might be the best approach to move mitochondria into the mainstream? The history of penicillin, for example, is more complex than the official narrative associated with it. While Alexander Fleming may not have been the first to observe the effects of penicillin, he was the first to give it its accepted name, a name that is now almost synonymous with modern medicine as we know it. It is not enough, perhaps, to have a good idea, and even a promising result; both idea and result require some level of plausibility to convince the more conservative observer. In many ways, this plausibility is about keeping the conversation going. One of the primary aims of The Guy Foundation is to support and facilitate this conversation towards its acceptance into mainstream dialogue. As such, it is gratifying to see how the Autumn Series has added new voices and new

insights into how this aim might be achieved. As suggested by Afshin Beheshti, perhaps engaging the public imagination through favourable narratives would be one way to proceed. As it happens, quantum biology owes its name to the physicist Pascual Jordan. At the same time, it perhaps owes its subsequent obscurity to Jordan's Nazi associations. In an age where space exploration has a growing audience, a focus on the physiological ramifications of off-world travel offers a microcosm in which to advance alternative approaches to medicine. To this end, in 2023, The Guy Foundation will be organising a symposium that will explore how space health could be a model of accelerated aging and disease outside of the specific enviro-genetic envelope that humankind is used to, giving rise to alternative ways of thinking in the biomedical realm. We are looking forward to continuing the excellent discussion.

December 2022