Quantum Biology and Biomanufacturing

May 2024, Version 1.1

A collaboration between the Quantum Biology Tech (QuBiT) Lab and Leverage

To learn more about our Bottlenecks Program, please visit our website.

Are Bioprocesses Quantum-Sensitive?

There is substantial evidence suggesting that quantum physics plays a role in the macroscopic behavior of biocompounds and cells.[1] There are several distinct mechanisms by which this could be the case; understanding any of them should make it possible to deploy quantum processes in the service of more effective biomanufacturing.

First, quantum processes may be involved in molecular recognition. As early as 1928, it has been proposed that "lock and key" models of molecular recognition are incomplete.[2] According to the quantum model, the "key" molecule provides not only the right shape, but the right vibrational signatures, which help electrons to tunnel and allow the signaling state to be more easily established.

Correlative data support this model for olfactory receptors,[3] and recent theories suggest that the same quantum model might also account for how viruses attach to cells,[4] how neurotransmitters are received by a target cell,[5] and how enzymes catalyze reactions.[6] If this model is correct, particular vibrational frequencies, which can be modeled and predicted, can be applied to biochemical reactions and cellular processes to enhance molecular recognition.

Second, a whole range of biological processes across the tree of life, including DNA repair,[7] cellular metabolism,[8] cell division rates,[9] and wound healing[10] respond to, and thus are controllable by, weak magnetic fields. In the cases in question, the effect size is largest with the presence or absence of a weak magnetic field, on the order of a cell phone's. This would not be expected classically, where effect size typically correlates directly with field strength, but should be expected if quantum phenomena, such as electron spin superpositions, are at work.[11]

If the quantum-driven model of weak magnetic field effects is correct, weak magnetic fields could be intelligently applied to increase the proliferation rate of insulin-producing bacteria or lab-grown meat cells,[12] to up- or down-regulate the metabolism of cells grown inside bioreactors,[13] and to bias the final macroscopic products of chemical reactions that are magnetosensitive.[14]

As a result, more effective biomanufacturing may be within reach. If quantum phenomena in biology can be modulated in a way that alters, for instance, cell division rates or the efficiency of molecular recognition, entirely new rules may start to apply to biomanufacturing.

The next step towards a new era of biomanufacturing is to progress from circumstantial evidence of quantum effects on bioprocesses to direct observational evidence. That in turn requires building custom quantum microscopes to look inside cells and see whether the relevant quantum phenomena survive for long enough to be biologically relevant and then learning to deterministically control them.

QuBiT / Leverage

The QuBiT Lab seeks to test the Quantum Biology Hypothesis and unambiguously refute or establish the existence of a quantum-to-biology link.[15] If quantum phenomena impact biological systems, there are likely ways to use that link to cause beneficial effects and defend against harmful ones. Greater understanding of quantum effects in biology can contribute substantially to medicine,[16] chemical manufacturing, drug discovery,[17] space exploration,[18] quantum computing,[19] and defense.[20] QuBiT was originally located at UCLA and is led by Clarice Aiello, the preeminent scientist in the field of quantum biology.

Leverage is providing operational support to QuBiT, helping it to obtain funding, and studying the bottlenecks in the field of quantum biology as part of its mission to advance areas in science and technology which have become stuck.[21,22] Leverage has more than a decade of experience overseeing and supporting complex research projects, providing as-needed help with hiring, fundraising, project planning, and research validation.

References

[1] Aiello, Clarice. "It's Time to Take Quantum Biology Research Seriously." Physics 16, no. 79 (May 2023). https://physics.aps.org/articles/v16/79

[2] Dyson, GM. "Some aspects of the vibration theory of odor." Perfumery Essent. Oil Rec. 19 (1928).

[3] Franco, M.I. et al. "Molecular vibration-sensing component in Drosophila melanogaster olfaction." Proceedings of the National Academy of Sciences, USA 108 (2011). https://doi.org/10.1073/pnas.1012293108

[4] Adams, Betony et al. "Quantum tunnelling in the context of SARS-CoV-2 infection." Sci Rep. 12 (2022). https://doi.org/10.1038/s41598-022-21321-1

[5] Hoehn, Ross D. et al. "Neuroreceptor Activation by Vibration-Assisted Tunneling." Sci. Rep. 5 (2015). https://doi.org/10.1038/srep09990

[6] Bruno, William J. and William Bialek. "Vibrationally enhanced tunneling as a mechanism for enzymatic hydrogen transfer." Biophys. J. 63 (1992). https://doi.org/10.1016/S0006-3495(92)81654-5

[7] Zwang, Theodore J. et al. "A Compass at Weak Magnetic Fields Using Thymine Dimer Repair." ACS Cent Sci. 4 (2018). https://doi.org/10.1021/acscentsci.8b00008

[8] Usselman, Robert J. et al. "The Quantum Biology of Reactive Oxygen Species Partitioning Impacts Cellular Bioenergetics." Scientific Reports 6 (2016). https://doi.org/10.1038/srep38543

[9] Zadeh-Haghighi, Hadi and Christoph Simon. "Magnetic field effects in biology from the perspective of the radical pair mechanism." J. R. Soc. Interface 19 (2022). https://doi.org/10.1098/rsif.2022.0325

[10] Henry, Steven L. et al. "The effect of magnetic fields on wound healing: experimental study and review of the literature." Eplasty. 8 (2008). https://pubmed.ncbi.nlm.nih.gov/18725953/

[11] Hore, P. J. and Henrik Mouritsen. "The Radical-Pair Mechanism of Magnetoreception." Annual Review of Biophysics 45 (2016). https://doi.org/10.1146/annurev-biophys-032116-094545

[12] Wong, Craig Jun Kit et al. "Brief exposure to directionally-specific pulsed electromagnetic fields stimulates extracellular vesicle release and is antagonized by streptomycin: A potential regenerative medicine and food industry paradigm." Biomaterials 287 (2022). https://doi.org/10.1016/j.biomaterials.2022.121658

[13] Tai, Yee Kit et al. "Magnetic fields modulate metabolism and gut microbiome in correlation with Pgc-1α expression: Follow-up to an in vitro magnetic mitohormetic study," FASEB J. 34 (2020). https://doi.org/10.1096/fj.201903005RR

[14] Steiner, Ulrich E. and Thomas Ulrich. "Magnetic field effects in chemical kinetics and related phenomena." Chem. Rev. 89 (1989). https://doi.org/10.1021/cr00091a003

Further Reading

[15] Leverage & QuBiT Lab. "Testing the Quantum Biology Hypothesis," version 1.7 (2024).

[16] Leverage & QuBiT Lab. "Quantum Biology and Health," version 1.0 (2024).

[17] Leverage & QuBiT Lab. "Quantum Biology and Drug Discovery," version 1.0 (2024).

[18] Leverage & QuBiT Lab. "Quantum Biology and Space Exploration," version 1.2 (2024).

[19] Leverage & QuBiT Lab. "Quantum Biology and Quantum Computing," version 1.3 (2024).

[20] Leverage & QuBiT Lab. "Quantum Biology and Defense," version 1.0 (2024).

[21] Leverage & QuBiT Lab. "Quantum Biology and Brain Function," version 1.0 (2024).

[22] Leverage & QuBiT Lab. "Quantum Biology and Artificial Intelligence," version 1.0 (2024).