Quantum Biology; From Classic Medical Physics to Quantum Medicine

Seyedeh Haniyeh Mortazavi (MSc)[1], Alireza Mehdizadeh (MD, PhD)[1,2]*

[1]Neuromodulation and Pain Research Center, Shiraz University of Medical Sciences, Shiraz, Iran
[2]Editor-in-Chief of the Journal of Biomedical Physics and Engineering, Shiraz University of Medical Sciences, Shiraz, Iran

Physics has advanced through conceptual leaps. The foundational work of 1666 established a mathematical framework for the natural world through Newton's laws of motion, gravitation, and the development of calculus. A second leap occurred in 1905, when Einstein proposed that light consists of discrete energy packets (photons) rather than a purely continuous wave [1]. This quantization underpins subsequent developments, including biophotons and coherent energy transfer in biological systems. Medicine has already integrated classical and early quantum physics through imaging, radiotherapy, and nuclear medicine; the next frontier is recognizing that quantum mechanics may operate functionally within living tissues at body temperature, particularly at the nanoscale where biological machinery functions. Rather than relying on isolated observations, the case for quantum biology rests on fundamental physical expectations and recurring empirical patterns. *First*, scale: biological processes such as electron and proton transfer in respiration, photosynthesis, and enzymatic reactions occur over angstrom to nanometer distances and femtosecond to picosecond timescales regimes governed by quantum rather than classical mechanics, making quantum effects the default expectation [2]. *Second*, decoherence and functional coherence: thermal noise in warm, wet cellular environments causes rapid decoherence, yet if biologically relevant events (e.g., energy transfer or bond breaking) occur on timescales comparable to or shorter than decoherence times or if the noise itself is structured rather than purely random quantum effects can still confer a functional advantage. Evolution may have shaped biological structures to exploit transient quantum coherence precisely when it is useful [3]. *Third*, and most persuasively, quantum signatures appear independently across diverse biological contexts, and this convergence rather than any single experiment is what strengthens the framework. In the Fenna Matthews Olson (FMO) complex of green sulfur bacteria, excitonic energy transfer exhibits wave-like coherent behavior that enhances efficiency beyond classical hopping models [4, 5]. Enzymatic catalysis often shows enhanced reaction rates and temperature independence consistent with quantum tunneling [3]. Avian magnetoreception relies on the radical-pair mechanism, in which electron spin coherence enables geomagnetic field sensing [6]. In the brain, modeling suggests entanglement between tubulin states and endogenous biophotons in neuronal microtubules, offering a potential mechanism for quantum enhanced information processing [7]. We remain agnostic on the Penrose Hameroff hypothesis linking microtubule coherence to consciousness; the evidence supports quantum involvement in certain neural processes, but its relation to subjective experience requires further rigorous testing. What unites these independent systems is a shared strategy transient quantum coherence exploited for functional advantage before decoherence sets in. If biological systems do

*Corresponding author:
Alireza Mehdizadeh
Department of Medical Physics and Engineering, 7th floor, Third Block, School of Medicine, Shiraz University of Medical Sciences, Zand Street, Shiraz, Iran
E-mail: alireza.mehdizadeh@gmail.com

Received: 29 June 2026
Accepted: 15 July 2026

exploit quantum effects, the primary challenge for medical physics shifts from measurement to accurate simulation of many body quantum dynamics, where classical computers struggle with exponential scaling and quantum computers can represent quantum states natively [8]. Quantum simulation could enable in silico testing of drug effects on coherent transport in enzymes, protein aggregation in neurodegenerative disease, and tubulin biophoton interactions a paradigm shift toward predictive, quantum level modeling in medical physics. Realizing this potential requires hardware that is practical outside a physics laboratory. Current superconducting and trapped ion platforms demand extreme operating conditions that limit accessibility. Solid state defect qubits particularly nitrogen vacancy (NV) centers in diamond offer a promising route to affordable, room-temperature operation: these systems maintain coherence at ambient conditions because of lattice isolation, and can be fabricated via scalable chemical vapor deposition [9, 10]. Similar defects in silicon carbide and other materials align well with existing semiconductor manufacturing, and combining defect qubits with photonic interconnects could yield robust, cost effective quantum processors suitable for medical physics departments. Quantum biology is grounded in the nanoscale physics of life, the feasibility of transient coherence, and convergent evidence across disparate systems, and this pathway now merits dedicated investment and collaboration. To realize its potential, the medical physics community should: integrate quantum science, biology, and computing into curricula; foster interdisciplinary groups focused on priority simulation targets such as enzyme coherence or microtubule dynamics; advocate for shared access to room-temperature quantum hardware; prioritize rigorous computational studies and experimental validation before any clinical translation; and emphasize evidence-based approaches throughout, so as to avoid overinterpretation. By embracing quantum simulation tools now, medical physics can move beyond classical descriptions toward deeper mechanistic understanding and, in time, novel therapeutic insight.

Authors' Contribution

SH. Mortazavi and AR. Mehdizadeh contributed to the conceptualization, methodology, and writing of the manuscript and read, modified, and approved the final version.

Conflict of Interest

AR. Mehdizadeh, Editor-in-Chief and Chairperson, was not involved in the peer-review and decision-making processes for this manuscript. The non-author, Editorial Board and reviewers oversaw the peer review process for this paper.

References

1. Einstein A. Über einem die Erzeugung und Verwandlung des Lichtes betreffenden heuristischen Gesichtspunkt. *Ann Phys.* 1905;**322**(6):132-48. doi: 10.1002/andp.19053220607.
2. Lambert N, Chen YN, Cheng YC, Li CM, Chen GY, Nori F. Quantum biology. *Nature Phys.* 2013;**9**(1):10-8. doi: 10.1038/nphys2474.
3. Brookes JC. Quantum effects in biology: golden rule in enzymes, olfaction, photosynthesis and magnetodetection. *Proc Math Phys Eng Sci.* 2017;**473**(2201):20160822. doi: 10.1098/rspa.2016.0822. PubMed PMID: 28588400. PubMed PMCID: PMC5454345.
4. Panitchayangkoon G, Hayes D, Fransted KA, Caram JR, Harel E, Wen J, et al. Long-lived quantum coherence in photosynthetic complexes at physiological temperature. *Proc Natl Acad Sci U S A.* 2010;**107**(29):12766-70. doi: 10.1073/pnas.1005484107. PubMed PMID: 20615985. PubMed PMCID: PMC2919932.
5. Engel GS, Calhoun TR, Read EL, Ahn TK, Mancal T, Cheng YC, et al. Evidence for wavelike energy transfer through quantum coherence in photosynthetic systems. *Nature.* 2007;**446**(7137):782-6. doi: 10.1038/nature05678. PubMed PMID: 17429397.
6. Aslam N, Zhou H, Urbach EK, Turner MJ, Walsworth RL, Lukin MD, Park H. Quantum sensors for biomedical applications. *Nat Rev Phys.* 2023;**5**(3):157-69. doi: 10.1038/s42254-023-00558-3. PubMed PMID: 36776813. PubMed PMCID: PMC9896461.
7. Ostovari M, Alipour A, Mehdizadeh AR. Entanglement between bio-photons and Tubulins in brain: implications for memory storage and information processing. *NeuroQuantology.* 2014;**12**(3):350-5. doi: 10.14704/nq.2014.12.3.766.
8. Feynman RP. Simulating physics with computers. *Int J Theor Phys.* 1982;**21**(6-7):467-88. doi: 10.1007/BF02650179.
9. Schirhagl R, Chang K, Loretz M, Degen CL. Nitrogen-vacancy centers in diamond: nanoscale sensors for physics and biology. *Annu Rev Phys Chem.* 2014;**65**:83-105. doi: 10.1146/annurev-physchem-040513-103659. PubMed PMID: 24274702.
10. Liu GQ, Pan XY. Quantum information processing with nitrogen–vacancy centers in diamond. *Chinese Phys B.* 2018;**27**(2):020304. doi: 10.1088/1674-1056/27/2/020304.

Citation: Mortazavi SH, Mehdizadeh AR. Quantum Biology; From Classic Medical Physics to Quantum Medicine. *J Biomed Phys Eng.* 2026;16(4):265-266. do: 10.31661/jbpe.v0i0.2606-2114.