The Quantum Biology of Reactive Oxygen Species

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ABSTRACT

Quantum biology is the study of quantum effects on biochemical mechanisms and biological function. Quantum biology arising from recent research that suggests that biological phenomena such as photosynthesis, avian navigation or olfaction may not only operate within the bounds of classical physics but also make use of a number of the non-trivial features of quantum mechanics, such as coherence, tunneling and, perhaps, entanglement.
The orientation-dependence of magnetic stimulation leads to specific changes in ROS levels. Our results reveal quantum effects in live cell cultures that bridge atomic and cellular levels by connecting ROS partitioning to cellular bioenergetics.

INTRODUCTION

The biological production of reactive oxygen species (ROS) in live cells can be influenced by coherent electron spin dynamics, providing a new example of quantum biology in cellular regulation. Oscillating magnetic fields at Zeeman resonance alter relative yields of cellular superoxide (O_2^-) and hydrogen peroxide (H_2O_2) ROS products, indicating coherent singlet-triplet mixing at the point of ROS formation.

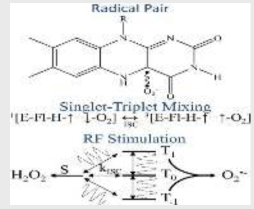


Fig.1. Flavin semi Quinone (FADH) and superoxide (O_2^-) spin-correlated radical pair (top).

METHODS AND MATERIALS

Cells were grown and maintained then seeded and allowed to rest for 24h under the same magnetic background conditions, after which timed magnetic exposures began.

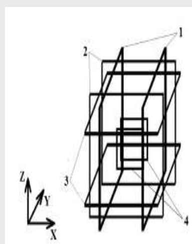
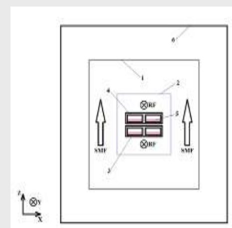


Fig.2. The diagram shown represents the experimental apparatus for magnetic fiel exposure.
Tri-dimensional representation of the tri-axial set used for controlling static an alternating electromagnetic fields. Square coil pairs in a Helmholtz configuration ar geometrically aligned to control the static magnetic field(SMF) and to compensate fo fluctuations in the ambient magnetic fields in the (1) horizontal (X) direction, (2 horizontal (Y) direction, and (3) vertical (Z) direction.
This diagram also depicts the placement of a square coil in Helmholtz configuratio for the generation of RF magnetic fields (4). A Faraday cage was also used in the R experiments to surround the setup to minimize RF reflections, but it is not shown i this diagram for clarity. /

Fig.3. The diagram shown represents the experimental apparatus for magnetic field exposure.
This figure depicts the directions of the magnetic fields with respect to the biological samples.(1)Atri-axial set of square coils in Helmholtz configuration for SMF generation in all three dimensions; (2) square coils in Helmholtz configuration for RF generation in the horizontal (Y) direction; (3) an individual six-well plate;(4)individual wells;(5)culture medium; and(6)a faraday cage.



RESULTS

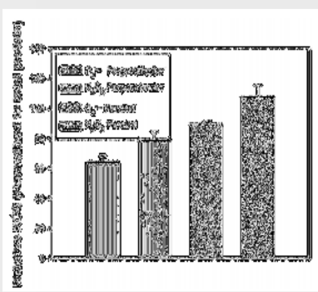


Fig.4. ROS product distributions illustrating the RF magnetic field orientation dependence at Zeeman resonance (1.4 MHz and 50T magnetic field).

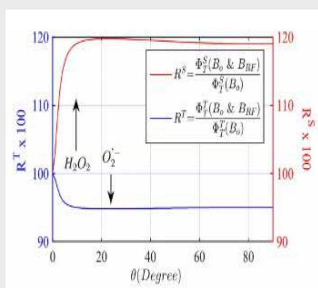


Fig .5. Numerical simulations of the effects of RF magnetic fields at Zeeman resonance on triplet (Φ_T^T, O^{2-}) and singlet (Φ_T^S,H_2O_2) yields of a triplet-born radical-pair reaction

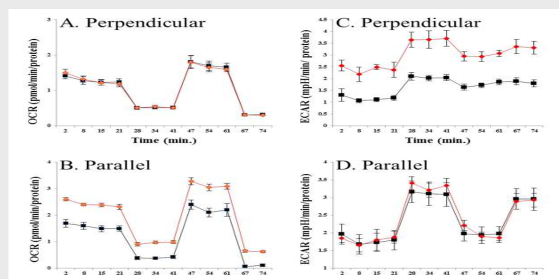


Fig.6. Bioenergetics profiles of HUVECs cultures monitored with a Seahorse XF Analyzer, comparing static alone(▪) magnetic fields(▪).

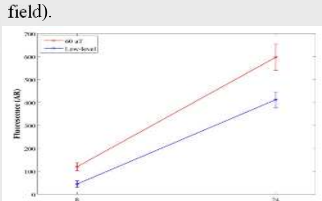


Fig.7. Low level fields decreased H_2O_2 production in endothelial cells.

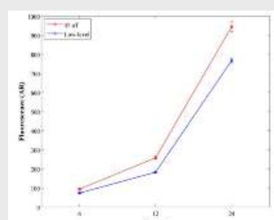


Fig.8. LLF decrease H_2O_2 production in HT1080 cancer cells ($p<0.05$). H_2O_2 production increased through out the exposure time. Low level fields decreased levels of H_2O_2 production in fibrosarcoma cells over 25% during the 24 hour exposure time.

CONCLUSION

The results demonstrate an overall magnetic field-induced biological effect that causes elevated H2O2 levels with accompanying decrease in cellular growth rates.

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