Research Area:
NASA (JSC) Collaborations

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In a collaboration with Tom Goodwin at NASA Johnson Space Center, we have developed 2-dimensional and 3-dimensional bioreactor systems to subject tissues to controlled electromagnetic fields. Experiments are currently in progress, and our preliminary data is extremely promising. We have subjected normal human neural progenitor (NHNP) cells to low level electromagnetic fields generated near electrically conductive plate electrodes (2-D) or within a field generated by a solenoid coil (3-D). The waveforms tested included sine waves, narrow pulses (delta function), and square waves. Cells were subjected to 17 days of electromagnetic field stimulation of all waveforms as well as a DC field.

The cells were not subjected to transverse electrical fields through the culture medium, as is often done in cell culture experiments employing electromagnetic fields, rather the cells were grown within the induced magnetic field surrounding the electrical conductor. For both the 2-D and 3-D systems, the magnetic field intensity was limited to ~ 70 mG. Magnetic field intensity was measured using a linear Hall effect sensor. For comparison, the Earth's magnetic field is approximately 500 mG at 45^{o} latitude. Rate of change of the magnetic fields was estimated on the basis of Maxwell's equations and the measured current transient response in both the conductive plate and the solenoid coil. The m**B** (micromagnetic) fields were applied in 5 separate interventions as:

(1) 10 Hz bipolar square waves,
(2) differentiated square waves (delta function); narrow pulses (200 ms) corresponding to each square wave edge,
(3) sine waves of the same amplitude and frequency as the square waves,
(4) DC (steady) m**B** fields, also of the same amplitude as the square wave, and
(5) control (no m**B** field).

Cell Responses: (relative to control)
Proliferation rate increased up to 4x
Morphology changes were macroscopically evident for large colonies of nerve cells in 2-D
Glucose metabolism +~60% in 3-D system
Gene array profiling indicated very significant increases in expression of classes of genes related to extra-cellular matrix production, growth, and metabolism.

All effects were greatest for square and delta functions, no difference between DC fields and control (no field).

Conclusions: Cells respond to the rate of change in the m**B** field (dB/dt), not to the peak field magnitude (Bmax) or total flux exposure. The high dB/dt of the square waves and the delta were both effective at influencing cellular response, whereas slowly varying (sine) or non varying (DC) fields had significantly reduced or no effect. Equivalently high peak fields or long exposure times (sine and DC, as well as square wave) were clearly not as important as the rate of change of the m**B** field. In this study, peak magnetic field amplitudes were ~ 70 mG, whereas the Earth's magnetic field on average is ~ 500 mG, but is not time varying (i.e., it is DC). The electromagnetic interventions carried out in this study were of course superimposed

upon the Earth's DC magnetic field. It is the time varying nature of the fields that apparently has the most significant influence on every aspect of the cellular response. We collectively term these time varying electromagnetic fields as TVEMFs.

The instrumentation and protocols for this series of experiments have been filed with the United States Patent and Trademark Office, and two manuscripts are currently in preparation.