Electromagnetic Fields in Manual Therapy

By Nadya Bell, RMT, CMRP

What could the MatrixMag be doing?

Plausible mechanisms linking physics to biological response

Overview

Cells have established biological sensitivities

Known EMF interaction Pathways

- Ion Dynamics (Hall effect; magnetohydrodynamics)
- Bioelectric Signalling

Nonlinear Response Reality

Electromagnetic fields may not directly ‘change tissue,’ but they can perturb bioelectric and fluid systems in ways that initiate downstream physiological responses.

Cells are Electrically Sensitive

Biological systems are electrically active environments

Cells are already electrical systems—fields don't act on inert matter.

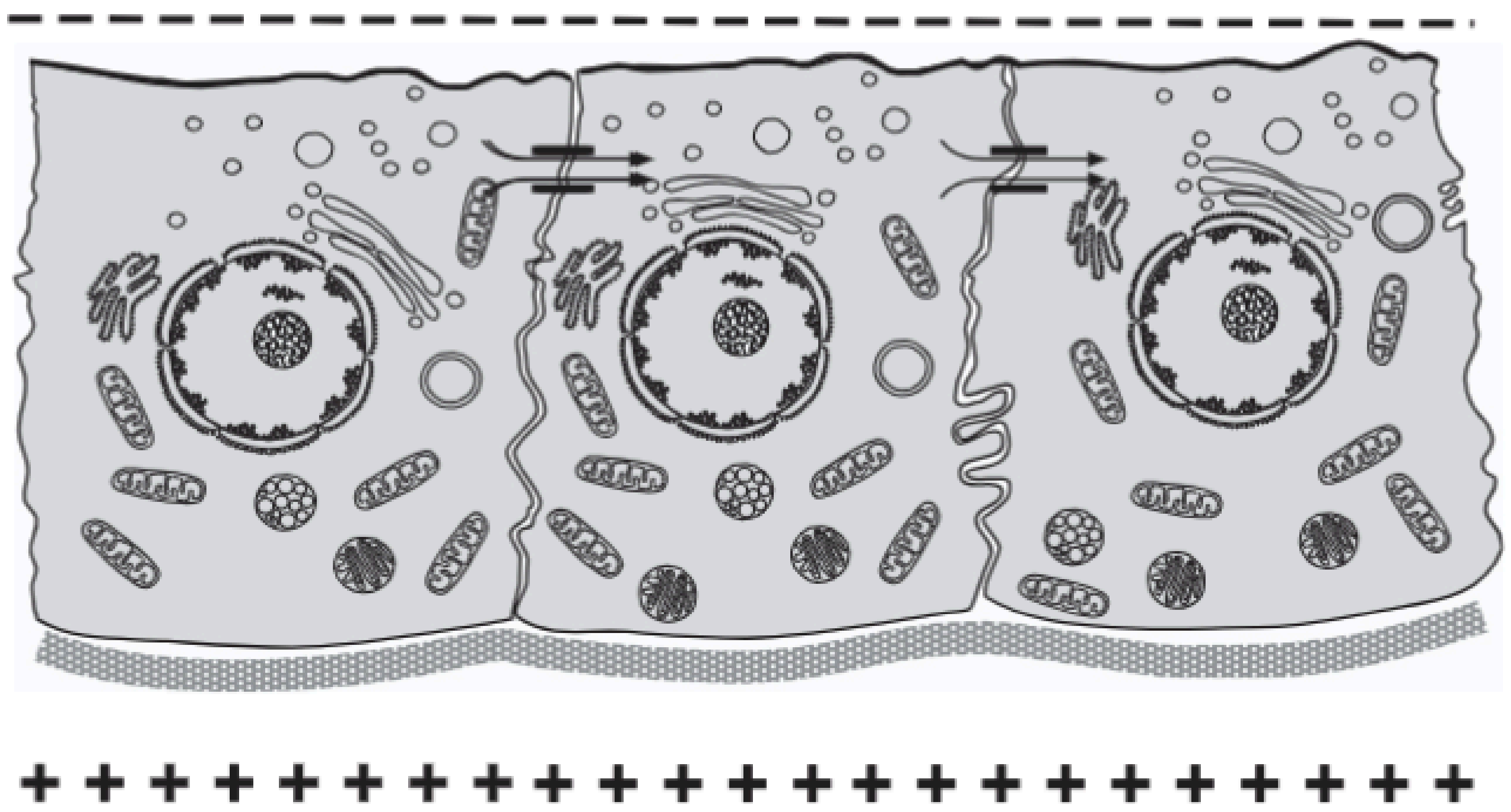

Fig. 8. DC EF potential generated by an epithelial layer (basement membrane at the bottom of the cells), transepithelial potential (TEP). Arrows between the neighboring cell membranes = ionic flow through gap junctions.

Available online at www.sciencedirect.com
ScienceDirect
ELSEVIER Progress in Histochemistry and Cytochemistry 43 (2009) 177–264
PROGRESS IN HISTOCHEMISTRY AND CYTOCHEMISTRY
www.elsevier.de/proghi

Electromagnetic effects – From cell biology to medicine

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Received 23 June 2008; accepted 25 July 2008

Abstract

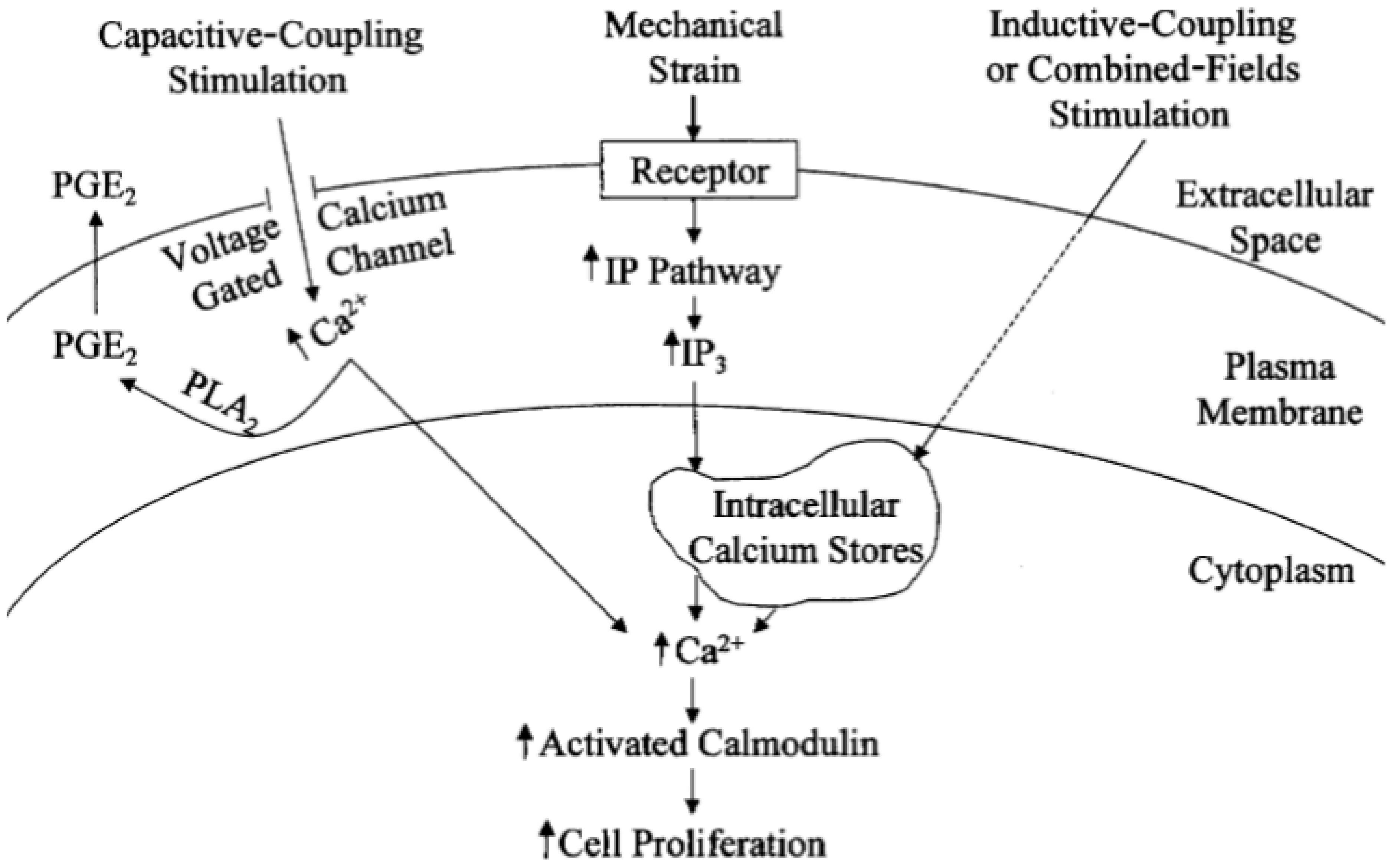
In this review we compile and discuss the published plethora of cell biological effects which are ascribed to electric fields (EF), magnetic fields (MF) and electromagnetic fields (EMF). In recent years, a change in paradigm took place concerning the endogenously produced static EF of cells and tissues. Here, modern molecular biology could link the action of ion transporters and ion channels to the "electric" action of cells and tissues. Also, sensing of these mainly EF could be demonstrated in studies of cell migration and wound healing. The triggers exerted by ion concentrations and concomitant electric field gradients have been traced along signaling cascades till gene expression changes in the nucleus.

Far more enigmatic is the way of action of static MF which come in most cases from outside (e.g. earth magnetic field).

All systems in an organism from the molecular to the organ level are more or less in motion. Thus, in living tissue we mostly find alternating fields as well as combination of EF and MF normally in the range of extremely low-frequency EMF. Because a bewildering array of model systems and clinical devices exits in the EMF field we concentrate on cell biological findings and look for basic principles in the EF, MF and EMF action.

(Funk, 2008)

Watch the Calcium!



"Schematic drawings shows the signal transduction pathways followed by electrical fields and mechanical strain."

Capacitive coupling
Mechanical Strain
Inductive Coupling

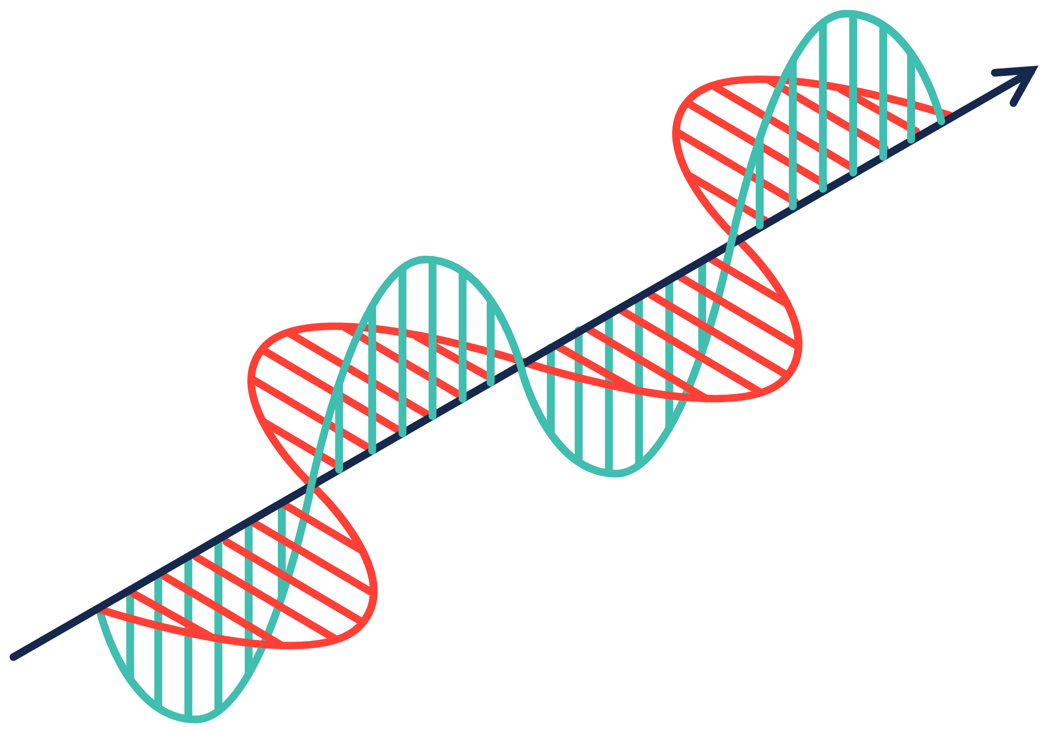
Calcium signalling is central to:
Contraction
Secretion
Repair proceses

Stimulation of Growth Factor Synthesis by Electric and Electromagnetic Fields. (Aaron, 2004)

Known EMF Interaction Pathways

Ion Dynamics and Resonance (Larmor Behaviour)
Lorentz force and Hall Effects
Magnetohydrodynamics
Reactive Oxygen Species and Nitric Oxide Signalling
Mechanotransduction Coupling

Field Physics: Ion Dynamics and Resonance



Magnetic fields in biological systems are spatially structured, not uniform

Static vs time-varying fields

Field geometry & gradients matter

Muesham and Pilla 2009

Bioelectromagnetics 30:476–488 (2009)

A Lorentz Model for Weak Magnetic Field Bioeffects: Part II—Secondary Transduction Mechanisms and Measures of Reactivity

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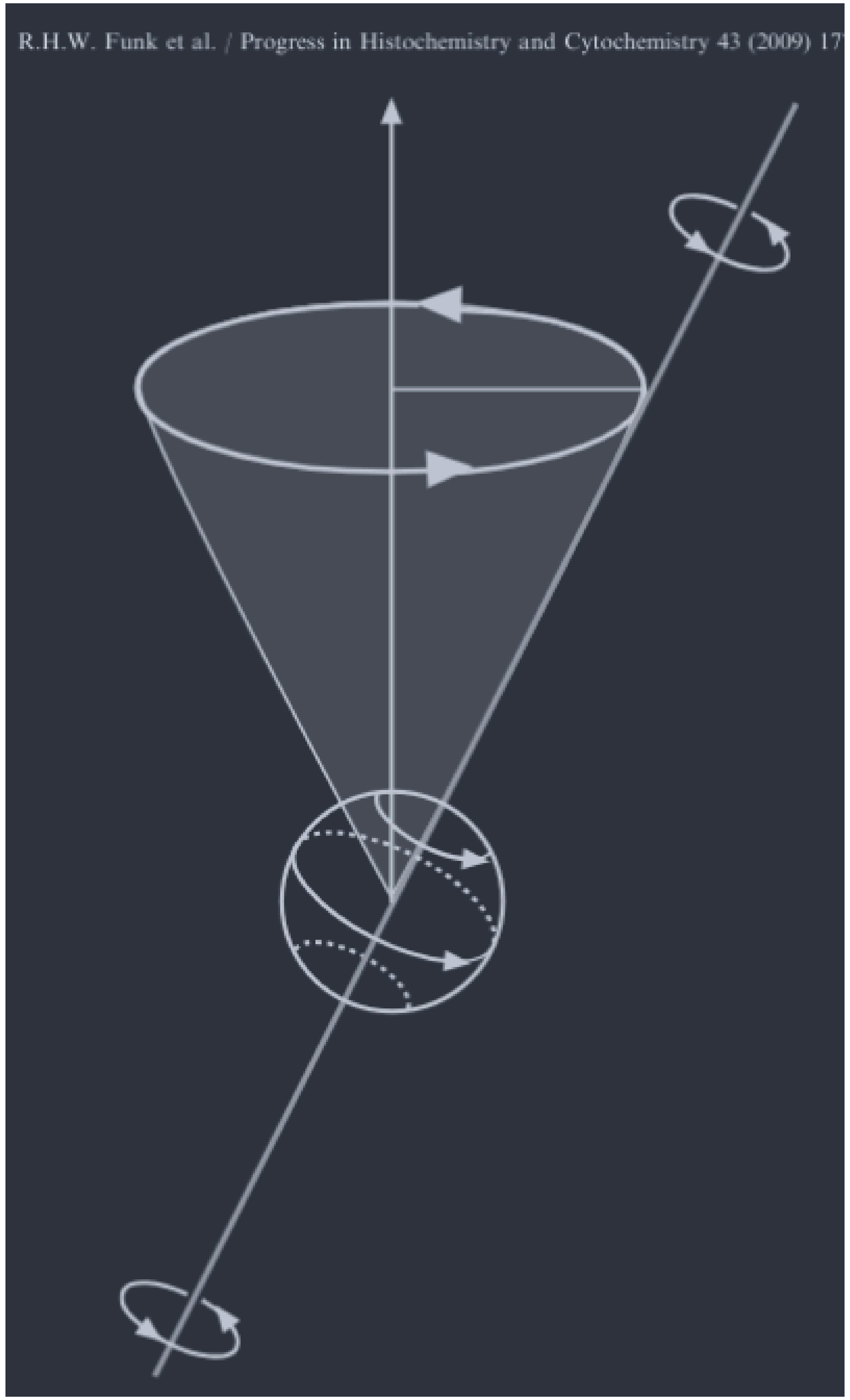
In Part I it was shown that the thermal component of the motion of a charged particle in an oscillator potential, that is, within a molecular binding site, rotates at the Larmor frequency in an applied magnetic field. It was also shown that the Larmor angular frequency is independent of the thermal noise strength and thus offers a mechanism for the biological detection of weak (μT-range) magnetic fields. Part II addresses the question of how the Larmor trajectory could affect biological reactivity. The projection of the motion onto a Cartesian axis measures the nonuniformity of the Larmor trajectory in AC and combined AC/DC magnetic fields, suggesting a means of assessing resonances. A physically meaningful measure of reactivity based upon the classical oscillator trajectory is suggested, and the problem of initial conditions is addressed through averaging over AC phases. AC resonance frequencies occur at the Larmor frequency and at other frequencies, and are dependent upon the ratio of AC/DC amplitudes and target kinetics via binding lifetime. The model is compared with experimental data reported for a test of the ion parametric resonance (IPR) model on data from Ca^{2+} flux in membrane vesicles, neurite outgrowth from PC-12 cells and a cell-free calmodulin-dependent myosin phosphorylation system, and suggests Mg^{2+} is the target for these systems. The results do not require multiple-ion targets, selection of isotopes, or additional curve fitting. The sole fitting parameter is the binding lifetime of the target system and the results shown are consistent with the literature on binding kinetics. Bioelectromagnetics 30:476–488, 2009.

Larmor Precession - Spirals

The specific frequency at which an ion circles around a magnetic field.
Or, the precessional motion of the axis of a charged particle. One circulation around the axis (small arrow) determines the Larmor frequency.

Ions in magnetic fields exhibit frequency-dependent behavior, resonance windows and selective sensitivity.
“Target system initial state” is crucial.
Biological responses may depend on frequency relationships, not just field strength.



Lorentz Force - Hall Effect

$$\vec{F} = q(\vec{E} + \vec{v} \times \vec{B})$$

Lorentz: the force causes charged particles to curve or change direction in a magnetic field.

In conductive fluids like blood, this can lead to very small charge separations (Hall effect), slightly altering local electric fields and ion distributions.

Interaction with thermal noise
Magnetic fields reshape how ions move—not just where they are

The Lorentz−Langevin equation of motion for a charged species such as an ion or ligand bound in a harmonic oscillator potential, subject to a DC magnetic field oriented up along the z-axis, in the presence of thermal noise is:

$$\frac{d^2 r}{dt^2} = -\beta \frac{dr}{dt} + \gamma \left[\frac{dr}{dt} \times B_0 \right] k - \omega^2 r + n$$

(Muehsam & Pilla 2009)

Hall effect → moving ions + magnetic field → charge separation

Hall Effect

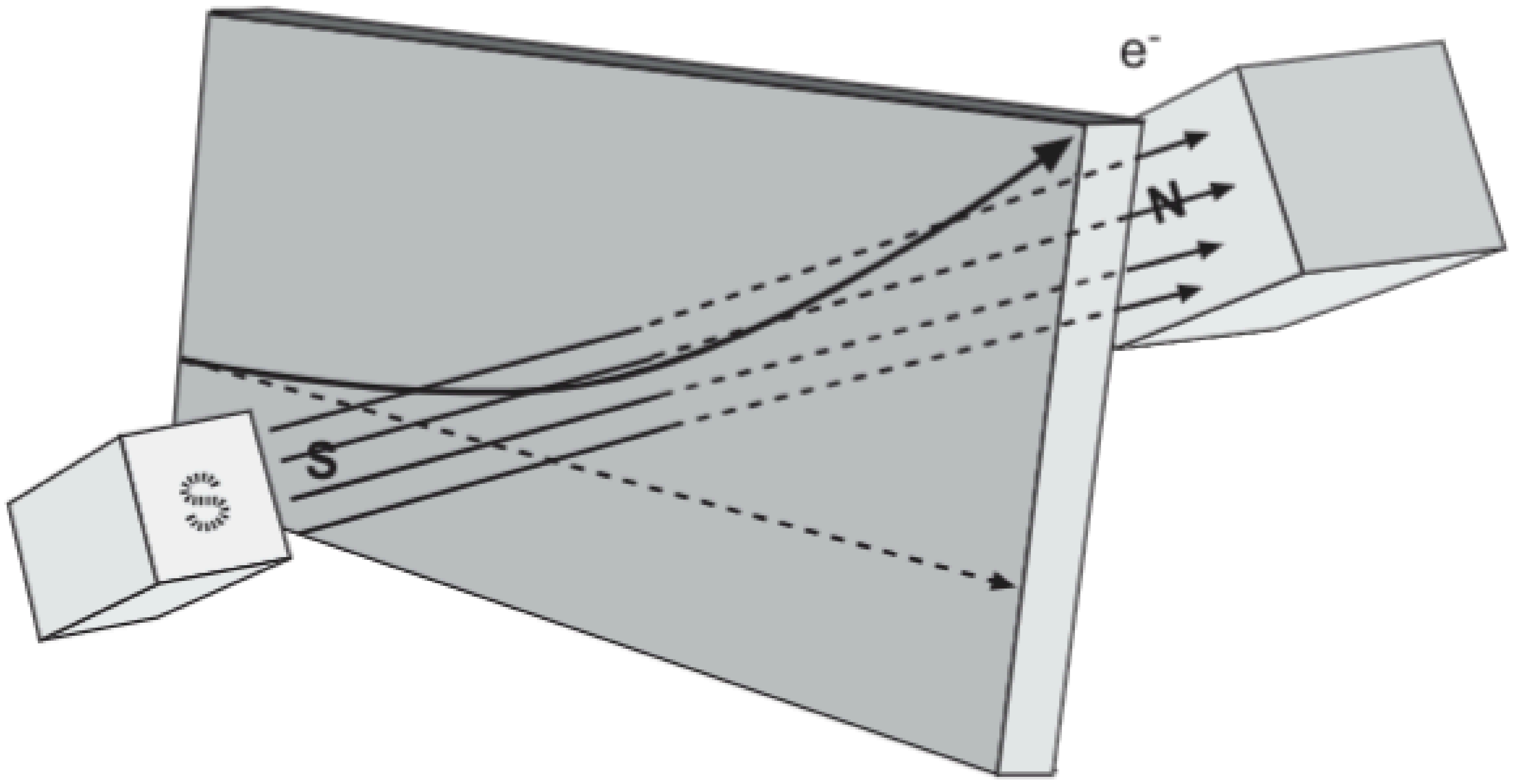


Fig. 26. Hall effect: deflection of charged particles of a current flow in a conductor by the Lorentz force (= entire electromagnetic force on a charged particle with charge q and velocity v) due to a perpendicular oriented magnetic field. Moving charges accumulate on one face of the conductor. This results in an asymmetric distribution of charge density across the "hall element".

Magnetohydrodyamics: the force meets the flow

International Journal of
INTELLIGENT SYSTEMS AND APPLICATIONS IN ENGINEERING
IJISAE
ISSN:2147-6799 www.ijisae.org Original Research Paper

Impact of Magnetic Fields on Pulsatile Blood Flow in the Presence of Microbial Suspensions: A Mathematical Investigation into Biofluid Dynamics and Infection Control

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Submitted: 10/01/2024 **Revised**: 18/02/2024 **Accepted**: 25/02/2024

Abstract: The study of pulsatile blood flow under magnetic fields has gained significant attention due to its implications in biofluid dynamics and infection control. This research presents a mathematical investigation into the impact of magnetic fields on blood flow in the presence of microbial suspensions, considering the interaction between blood plasma, red blood cells, and microbial particles. Using magnetohydrodynamic (MHD) principles, we formulate and analyze a system of governing equations incorporating the effects of Lorentz force, viscosity variations, and microbial diffusion. The mathematical model is developed based on Navier-Stokes equations, Maxwell's equations, and microbial transport models, accounting for the influence of an externally applied magnetic field on velocity distribution, microbial concentration, and overall flow stability. Numerical simulations are performed to explore the effect of different magnetic field strengths on blood flow resistance and microbial dynamics. The results indicate that stronger magnetic fields significantly alter velocity profiles, leading to enhanced microbial dispersion and potential reduction in infection spread. Additionally, the interaction between electromagnetic forces and microbial particles affects blood viscosity, influencing shear stress distribution within the vessels. The findings of this study provide critical insights into the role of magnetic fields in medical applications, such as magnetically guided drug delivery, infection mitigation, and targeted therapies. This research contributes to the growing field of bioelectromagnetics and medical physics, offering potential advancements in non-invasive medical treatments and controlled blood flow management.

Begum 2024

Blood flow modeled using fluid dynamics
Navier–Stokes equations, Coupled with electromagnetic forces
(Lorentz force) acting on conductive blood

The mathematical models suggest magnetic fields may influence blood velocity, viscosity and transport dynamics

Changes in flow → redistribution of:
shear stress
particle (microbial / cellular) concentration
Effects are spatially non-uniform (e.g., wall vs centerline differences) and
time-dependent (pulsatile flow)

Nonlinear Response Reality

OPEN ACCESS Freely available online PLOS ONE

Non-Thermal Radio Frequency and Static Magnetic Fields Increase Rate of Hemoglobin Deoxygenation in a Cell-Free Preparation

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Abstract

The growing body of clinical and experimental data regarding electromagnetic field (EMF) bioeffects and their therapeutic applications has contributed to a better understanding of the underlying mechanisms of action. This study reports that two EMF modalities currently in clinical use, a pulse-modulated radiofrequency (PRF) signal, and a static magnetic field (SMF), applied independently, increased the rate of deoxygenation of human hemoglobin (Hb) in a cell-free assay. Deoxygenation of Hb was initiated using the reducing agent dithiothreitol (DTT) in an assay that allowed the time for deoxygenation to be controlled (from several min to several hours) by adjusting the relative concentrations of DTT and Hb. The time course of Hb deoxygenation was observed using visible light spectroscopy. Exposure for 10–30 min to either PRF or SMF increased the rate of deoxygenation occurring several min to several hours after the end of EMF exposure. The sensitivity and biochemical simplicity of the assay developed here suggest a new research tool that may help to further the understanding of basic biophysical EMF transduction mechanisms. If the results of this study were to be shown to occur at the cellular and tissue level, EMF-enhanced oxygen availability would be one of the mechanisms by which clinically relevant EMF-mediated enhancement of growth and repair processes could occur.

Citation: Muehsam D, Lalezari P, Lekhraj R, Abruzzo P, Bolotta A, et al. (2013) Non-Thermal Radio Frequency and Static Magnetic Fields Increase Rate of Hemoglobin Deoxygenation in a Cell-Free Preparation. PLoS ONE 8(4): e61752. doi:10.1371/journal.pone.0061752

Editor: Robert Lafrenie, Sudbury Regional Hospital, Canada

Pulsed radiofrequencies and Static Magnetic Fields can change:
Hemoglobin deoxygenation
Reaction kinetics

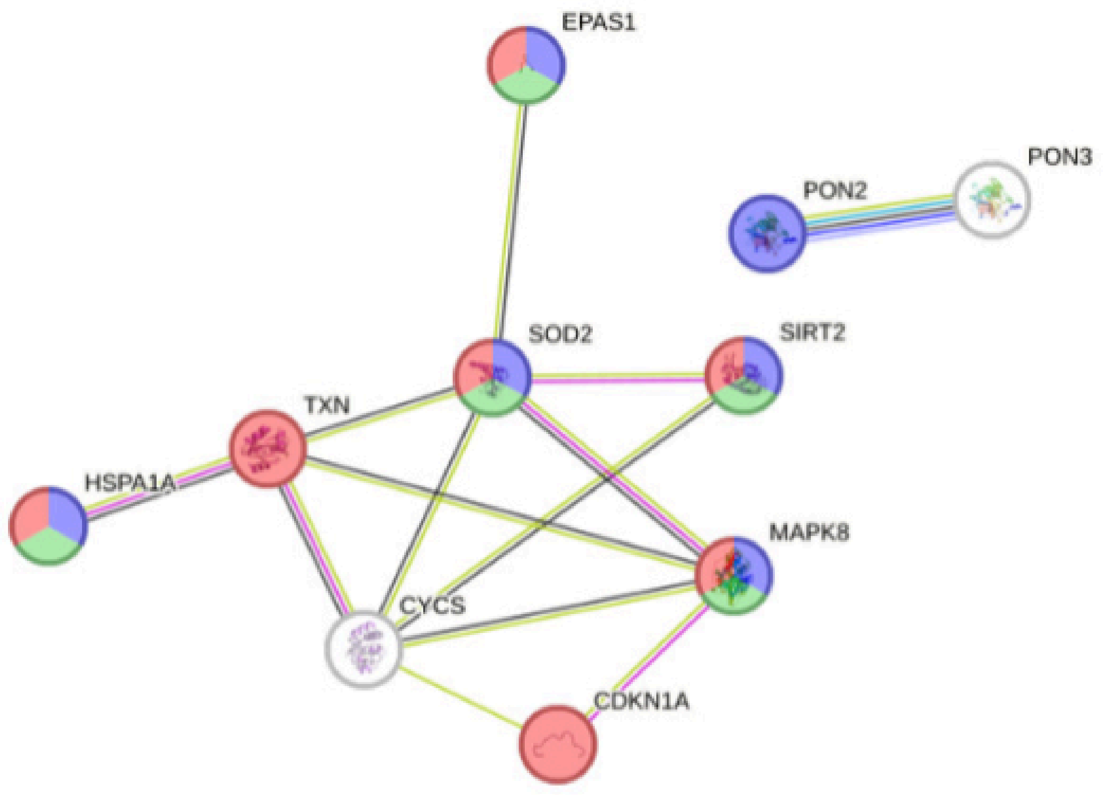
Small physical forces couple into sensitive nonlinear cellular and organism-level systems.

Muehsam 2013

From Physics to Biology

Cellular effects of PEMF propagate into organism scale biochemical processes. These are not just immediate physical effects—they influence cellular repair, growth and stress signals over a longer time.

Maiullari identified 10 Proteins Modulated by PEMF found to be genetically linked to responding to oxidative stress pathways



Biological Process (Gene Ontology)

GO-term	description	count in network	strength	false discovery rate
GO:0006979	Response to oxidative stress	6 of 368	1.51	0.00014
GO:0034599	Cellular response to oxidative stress	5 of 224	1.64	0.00038
GO:0009628	Response to abiotic stimulus	7 of 1107	1.1	0.00073

“Pulsed Electromagnetic Fields Induce Skeletal Muscle Cell Repair by Sustaining the Expression of Proteins Involved in the Response to Cellular Damage and Oxidative Stress” (Maiullari 2023)

Emergent Physiology

System-level effects are variable and state-dependent

Observed or reported effects include:

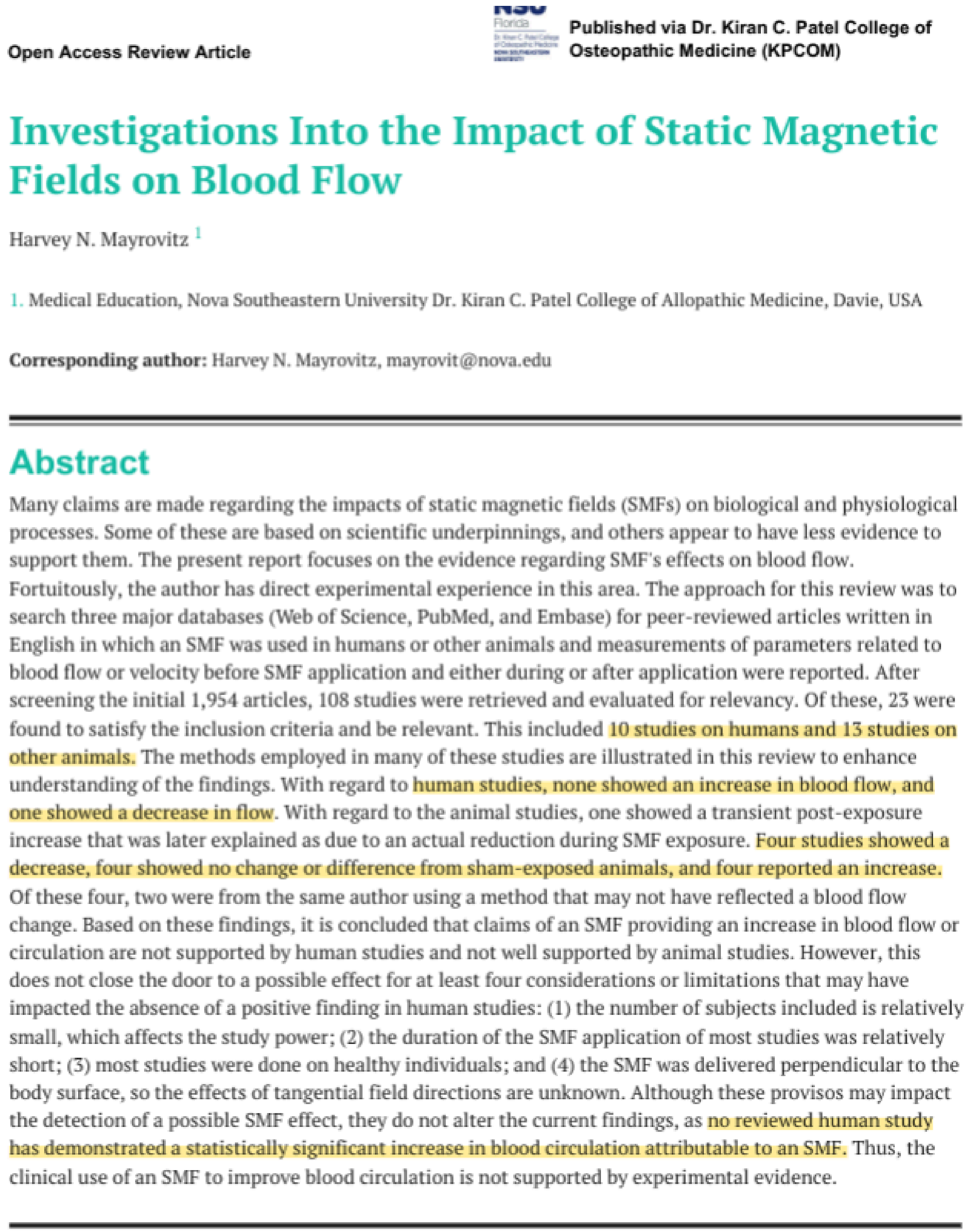
Blood flow changes

Perfusion variability

Shear stress modulation

Nitric oxide release

Same stimulus → different outcomes depending on baseline state



Open Access Review Article

Published via Dr. Kiran C. Patel College of Osteopathic Medicine (KPCOM)

Investigations Into the Impact of Static Magnetic Fields on Blood Flow

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Abstract

Many claims are made regarding the impacts of static magnetic fields (SMFs) on biological and physiological processes. Some of these are based on scientific underpinnings, and others appear to have less evidence to support them. The present report focuses on the evidence regarding SMF's effects on blood flow. Fortuitously, the author has direct experimental experience in this area. The approach for this review was to search three major databases (Web of Science, PubMed, and Embase) for peer-reviewed articles written in English in which an SMF was used in humans or other animals and measurements of parameters related to blood flow or velocity before SMF application and either during or after application were reported. After screening the initial 1,954 articles, 108 studies were retrieved and evaluated for relevancy. Of these, 23 were found to satisfy the inclusion criteria and be relevant. This included 10 studies on humans and 13 studies on other animals. The methods employed in many of these studies are illustrated in this review to enhance understanding of the findings. With regard to human studies, none showed an increase in blood flow, and one showed a decrease in flow. With regard to the animal studies, one showed a transient post-exposure increase that was later explained as due to an actual reduction during SMF exposure. Four studies showed a decrease, four showed no change or difference from sham-exposed animals, and four reported an increase. Of these four, two were from the same author using a method that may not have reflected a blood flow change. Based on these findings, it is concluded that claims of an SMF providing an increase in blood flow or circulation are not supported by human studies and not well supported by animal studies. However, this does not close the door to a possible effect for at least four considerations or limitations that may have impacted the absence of a positive finding in human studies: (1) the number of subjects included is relatively small, which affects the study power; (2) the duration of the SMF application of most studies was relatively short; (3) most studies were done on healthy individuals; and (4) the SMF was delivered perpendicular to the body surface, so the effects of tangential field directions are unknown. Although these provisos may impact the detection of a possible SMF effect, they do not alter the current findings, as no reviewed human study has demonstrated a statistically significant increase in blood circulation attributable to an SMF. Thus, the clinical use of an SMF to improve blood circulation is not supported by experimental evidence.

Mayrovitz 2025; Begum 2024; Maiullari 2023

Bioelectric Integrated Model

Fields

↓

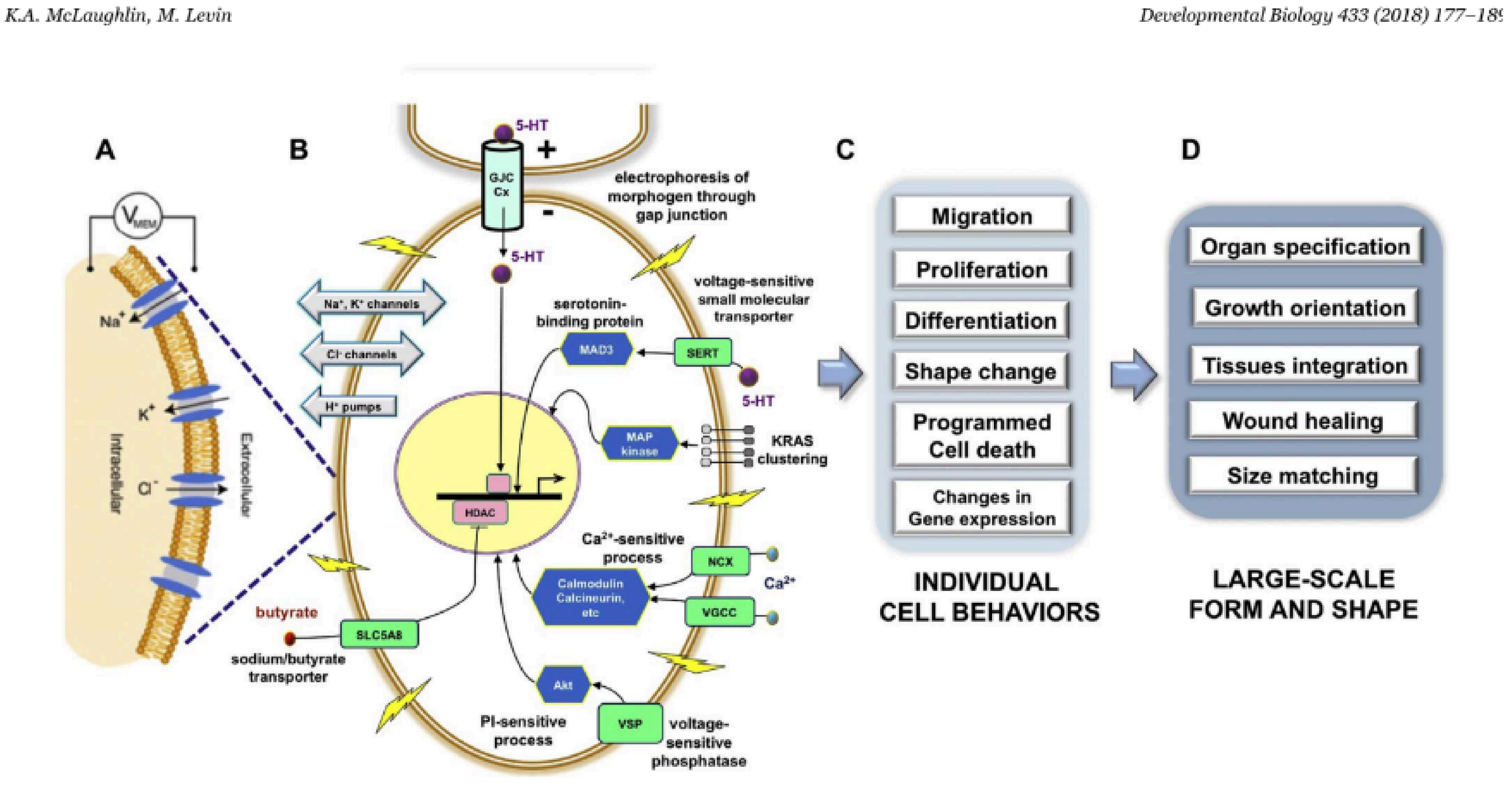
Membrane voltage changes

↓

Signaling (mechanical, molecular, bioelectric, genetic)

↓

System and tissue adaptation over time



Michael Levin's work (2018) shows us that interventions targeting voltage gradients within the body have the capacity to alter the information that our cells use to determine cell behaviour and morphology

Time Dimension

Electromagnetic fields act as triggers, rather than continuous drivers

Immediate (minutes):
Ion movement
Flow changes
Temperature / tone change

Short-term (hours):
NO signaling
vascular modulation

Delayed (24–72 hrs):
Gene expression
protein synthesis
tissue remodeling