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EDITED AND REVIEWED BY
Ralf Metzler,
University of Potsdam, Germany

*CORRESPONDENCE
Leonardo Makinistian,
lmakinistian@unsl.edu.ar

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Editorial: Interactions of magnetic fields with living cells

Leonardo Makinistian[1]*, Jonne Naarala[2] and Guijun Wan[3]

[1]Laboratory of Magnetobiology (MBLab), Department of Physics and Institute of Applied Physics, INFAP (UNSL-CONICET), San Luis, Argentina, [2]University of Eastern Finland, Department of Environmental and Biological Sciences, Kuopio, Finland, [3]Department of Entomology, College of Plant Protection, Nanjing Agricultural University, Nanjing, China

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Editorial on the Research Topic
Interactions of magnetic fields with living cells

1 What can be found in this Research Topic?

After their recent outstanding review on the biological effects of magnetic fields (MF, both static and varying), approached from the perspective of the radical pair mechanism [1], Zadeh-Haghighi et al. contribute a theoretical piece focused on hypomagnetic fields (HMFs) to this collection, suggesting that they could (and according to their model should) produce greater effects than fields above the geomagnetic field (GMF). Their model, along with more sophisticated ones, e.g., those involving triads of radicals [2], are to be put to experimental test.

Although far from being a direct and sound proof of their conclusions, it is informative that, in a follow-up to a remarkable previous study [3], Luo et al. reported effects of the HMF on the neurogenic niche and adult neurogenesis in the hippocampi of mice, as well significant effects on their cognitive function. They found that an 8-week HMF exposure induces neurogenic niche abnormalities, contributing to adult hippocampal neurogenesis impairments, with concomitant cognitive dysfunction and anxiety.

Moreover, in line with the results reported by Luo et al., Krylov et al. showed that HMFs can have a significant effect on zebrafish development. They demonstrated that the exposure of zebrafish embryos to HMFs leads to increased embryo mortality, the appearance of abnormal phenotypes, and a significant increase in the embryo's heart rate.

By contrast, Kinsey et al. found no significant effects with HMFs. In a follow-up to a previous study [4], they demonstrated that a weak static MF (0–900 μT) affects planarian regeneration through the modulation of superoxide, and the effects oscillated in the explored range, with the greatest observed at fields above the GMF. They studied the ROS-related mechanisms underlying the observed changes in regeneration in detail and thoroughly discussed them in the context of the current literature. Furthermore, their results showed with striking clarity that a 100-μT change in the SMF can not only produce a statistically significant change but also a change in the sign of the effect: stimulation instead of inhibition. This gives a powerful hint about not only the precision required when measuring the MF in an experiment but also on how fine the increments of the MF should be when screening in a given range. Another remarkable study in this area was carried out by Gurhan *et al.* [5] on HT-1080 fibrosarcoma cells. It is clear that much more research is needed on both ranges: the HMF and that between the GMF and, say, 1 mT (with increments no greater than 100 μT).

Three orders of magnitude above, Fei et al. showed that a prolonged exposure to a 1.1 T static MF for 10 days increased oxidative stress, blood glucose, and lipid levels in the mollusc *Elysia leucolegnote* and decreased its immunity and worsened its physiological condition. Although the authors emphasize the effects of MFs from submarine cables, we note here that their results are, indeed, also of interest to the discussion on the possible health effects of MFs on magnetic resonance imaging (MRI) patients and workers [6, 7].

In another contribution to this Research Topic, Ren et al. demonstrated a rapid and reversible behavioral response of *Xenopus* tadpoles to a static 0.1–80 mT MF for 10 min, both in the presence of light and in darkness, concluding that the presence of light is not indispensable for the magnetosensation mechanism in those vertebrates. Their method presents particularly attractive features, such as low cost and the capability of real-time monitoring of responses to the MF. The authors have worked for years on the subject and have reported numerous interesting findings, including with regard to mice subjected to HMFs [8].

All in all, let it be noted that in this succinct collection, magnetic fields (or the deprivation of them) were shown to affect the fundamental processes of living cells regarding embryogenesis, regeneration, physiological variables, and behavior in organisms as dissimilar as mice, fish, planarians, molluscs, and frogs.

Moreover, in the controversial domain of magnetogenetics [9, 10], Tong et al. evaluated several mutants of the wild-type pigeon clMagR. Among them, they found one that showed greater stability and sensibility to MFs. The authors propose it as a prototype for further studies of magnetoreception.

It should be emphasized that the scope of magnetobiology goes much further than the pure curiosity of a minor portion of the scientific community. In fact, it deals with a physical agent (MF) that, although poorly understood and usually disregarded, is a ubiquitous presence stemming not only from the planet's magnetism but also from practically all electrical and electronic devices. This has been, and still is, a source of concern for the general public, governments, and international organizations. Misek et al. contributed in this regard, along with many others (e.g., [11]), and these studies are necessary to provide a proper assessment of everyday life exposure.

2 What was not included in this Research Topic?

The study of the interaction of magnetic fields with living cells explores a vast realm at the intercross of biology, physics, and chemistry. It encompasses a wide diversity of phenomena, including the ones touched on in the articles gathered here but also many more. Aspects related to epidemiology, bio-physico-chemical mechanisms of interaction (other than the radical pair mechanism), health effects (both detrimental and beneficial), and biotechnological applications (e.g., seed magnetopriming) were not represented in this collection. The interested reader is encouraged to delve deeper into this relatively young yet fascinating avenue of scientific endeavor. As a step in that direction, we suggest visiting specialized journals that have gathered hundreds of articles on magnetobiology during the last 4 decades or so, such as *Bioelectromagnetics* and *Electromagnetic Biology and Medicine*. The wealth of reports found in them—along with references therein—should allow for a solid first approach to the construction of a rather comprehensive panorama of the state of the art, with its strengths and weaknesses and, notably, its challenging complexity.

Author contributions

LM wrote the first draft of the manuscript. The three authors contributed to and approved the final version of the manuscript.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

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