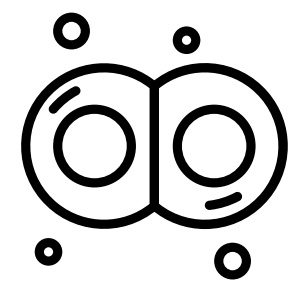
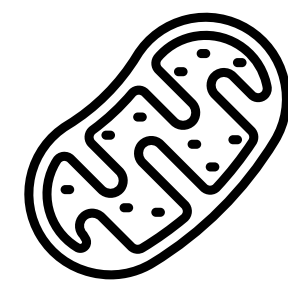


A real biological knob! Weak magnetic fields control physiology:
40+ years of widespread, organism- and cell type-agnostic correlative data
consistent with electron spin-dependent chemical reactions

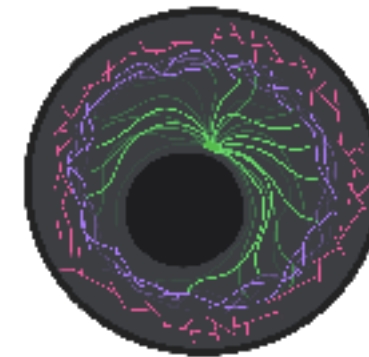
weak magnetic fields (\approx cell phone strength!) can up- and down-regulate, among others:



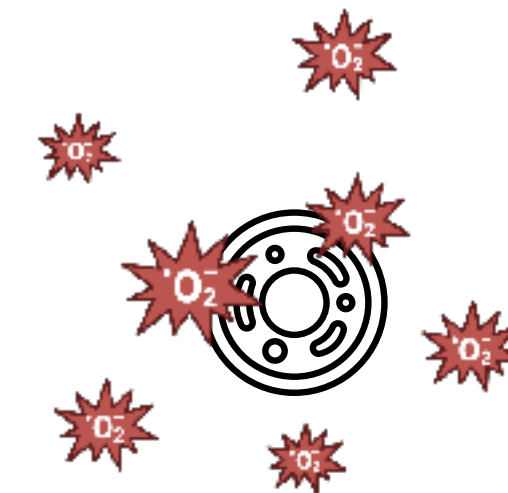
cell proliferation



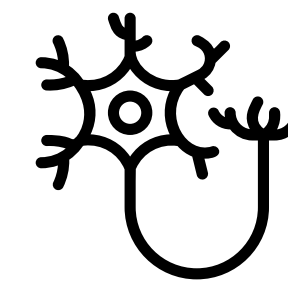
respiration
& metabolism



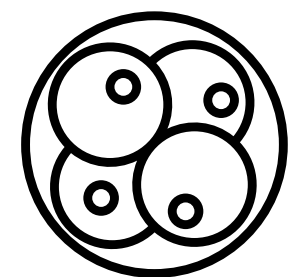
migration
& cytoskeleton



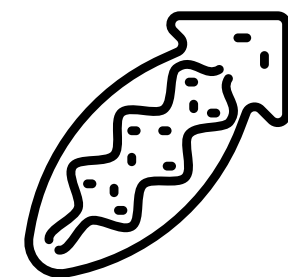
oxidative stress



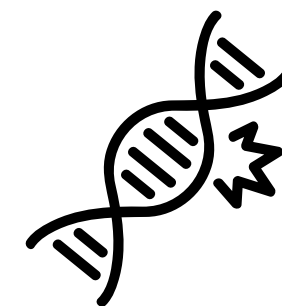
ion channel
functioning



embryogenesis



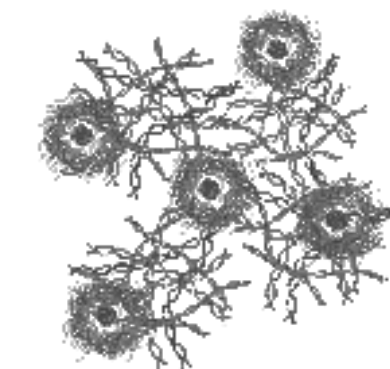
regeneration
& differentiation



DNA repair
& methylation

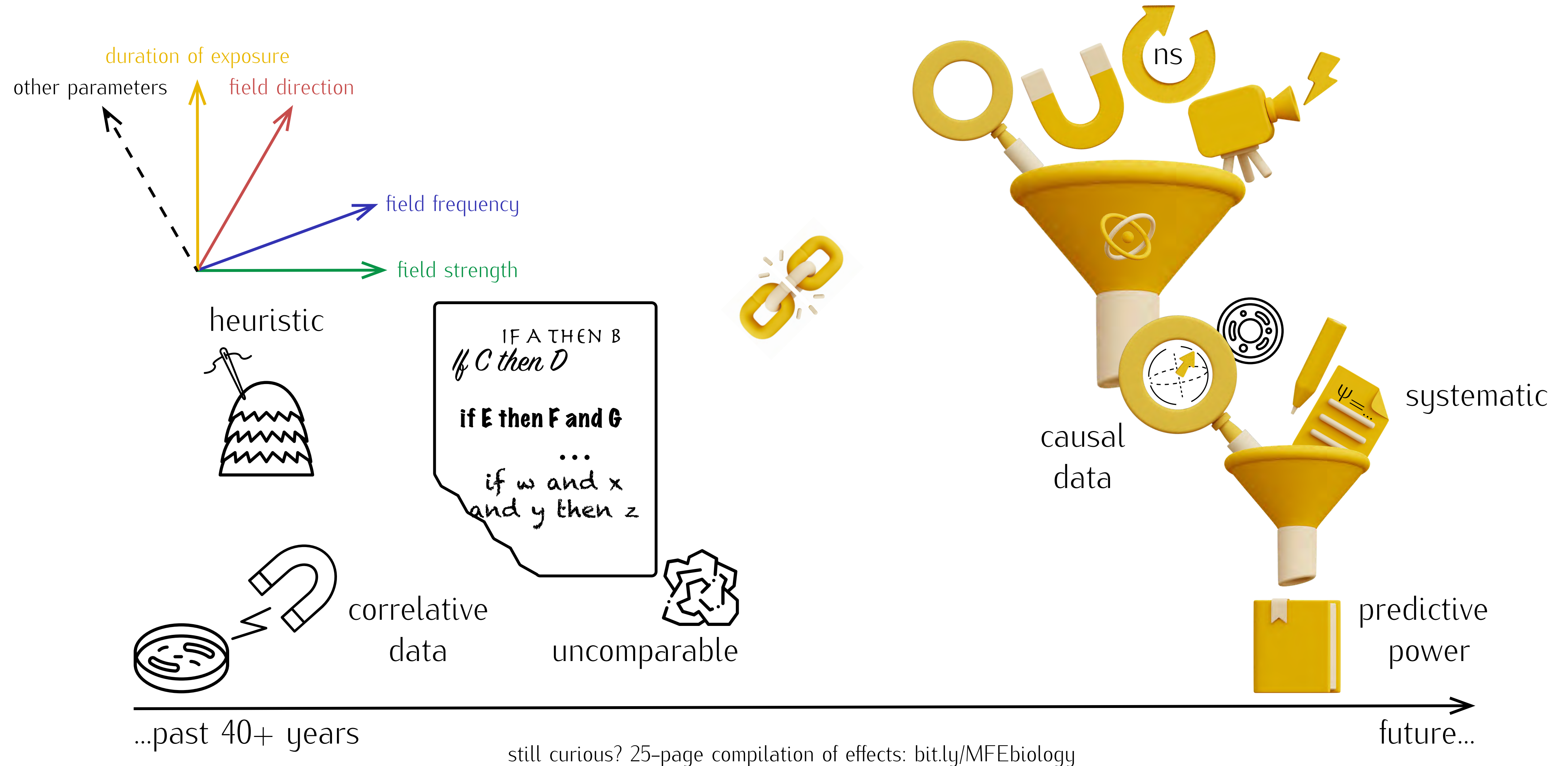


oxidative
phosphorylation

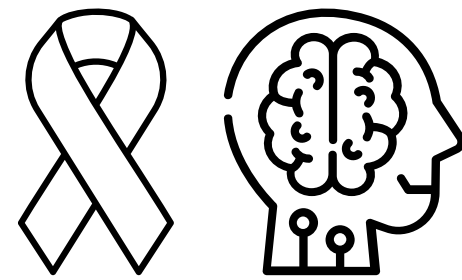
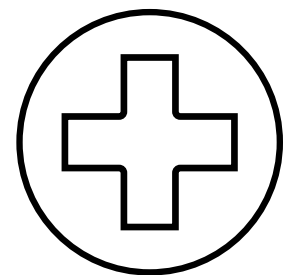
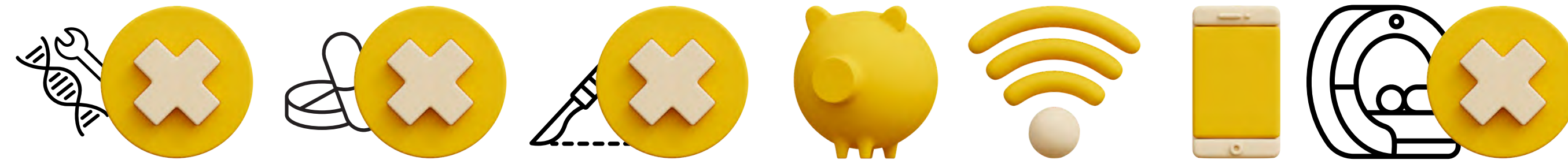


τ protein
aggregation

A real biological knob! Weak magnetic fields control physiology:
novel quantum instrumentation will yield
the codebook on how to deterministically control spins in biology for function



A real biological knob! Weak magnetic fields control physiology:
 endogenous, non-chemical, non-invasive, cheap, remotely-actuated, portable
electromagnetic interventions informing a myriad of fields



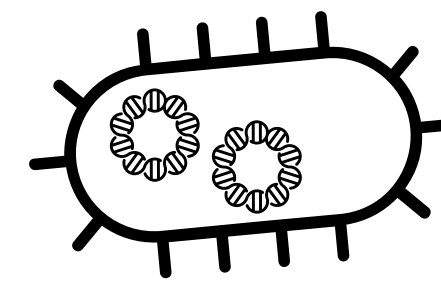
theranostics



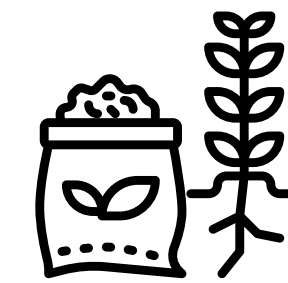
performance



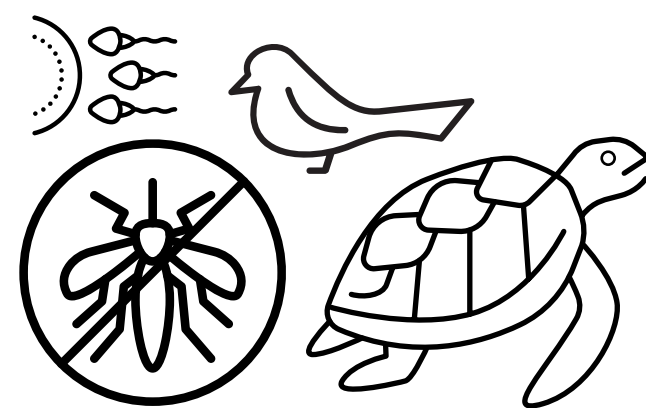
anti-aging



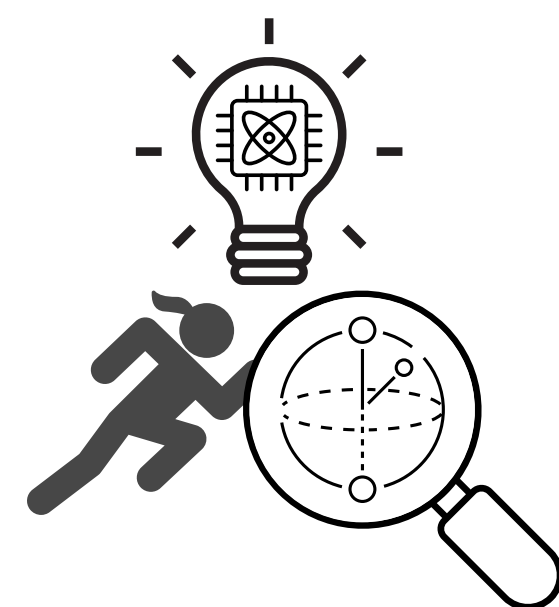
biomanufacturing



food security



native behavior
& origin of life



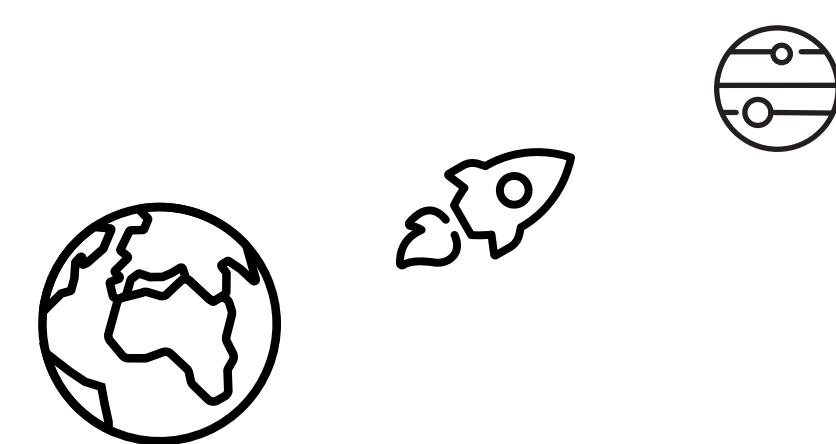
quantum tech
inspired by nature



electromagnetics
policy advisory

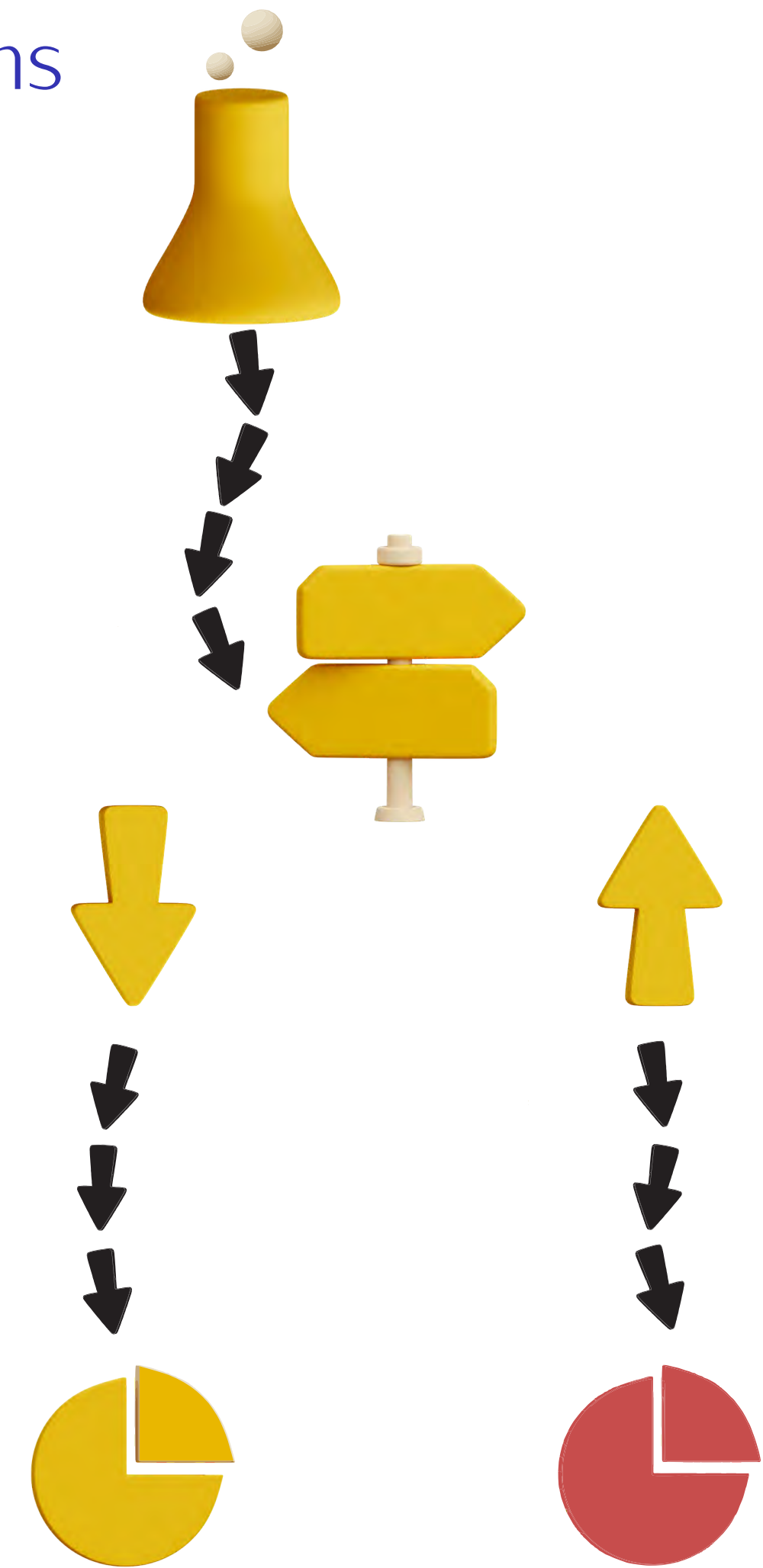


electromagnetic threat
countermeasures

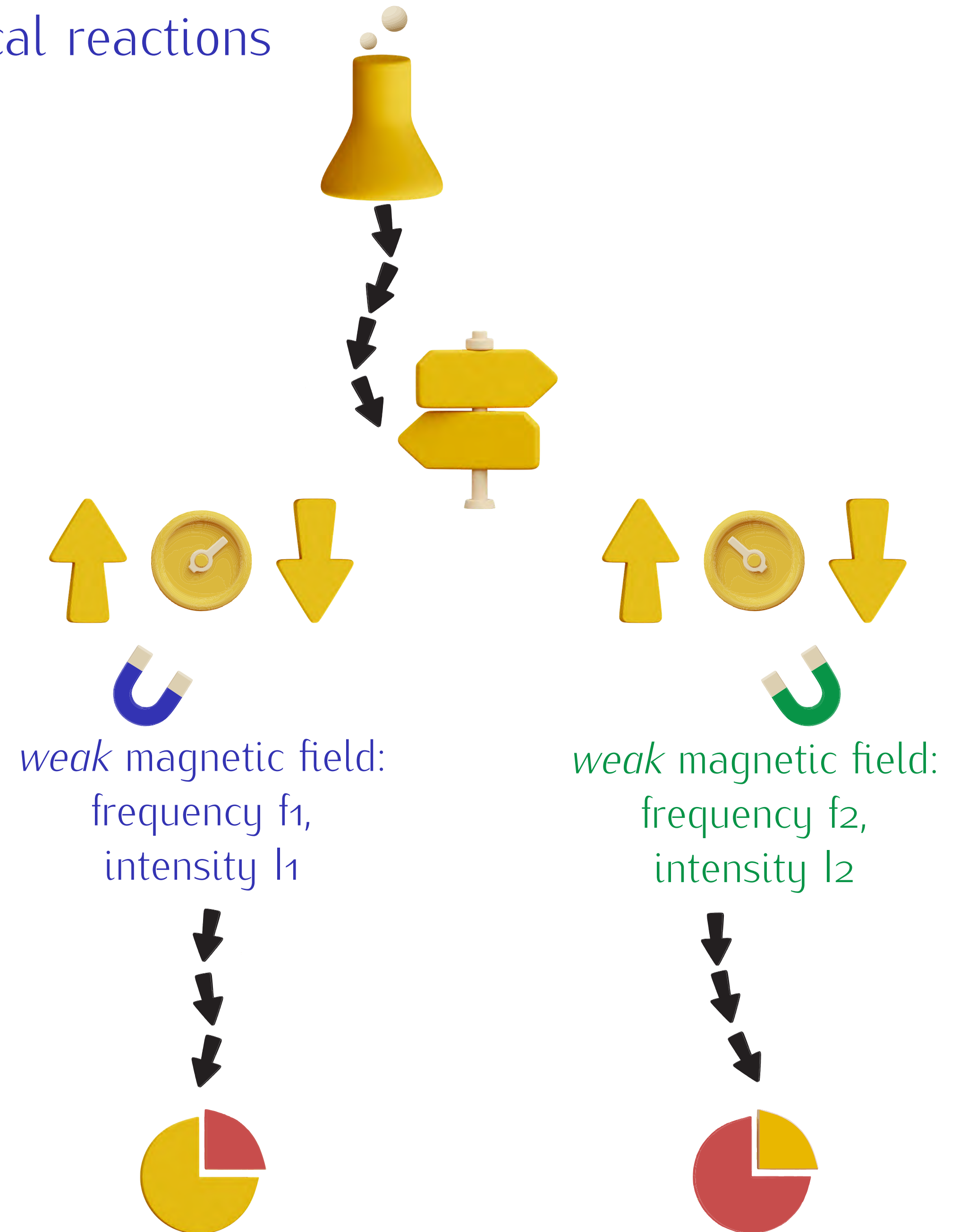


space travel
& colonization

Weak magnetic fields can alter the final products of chemical reactions that are electron spin-sensitive

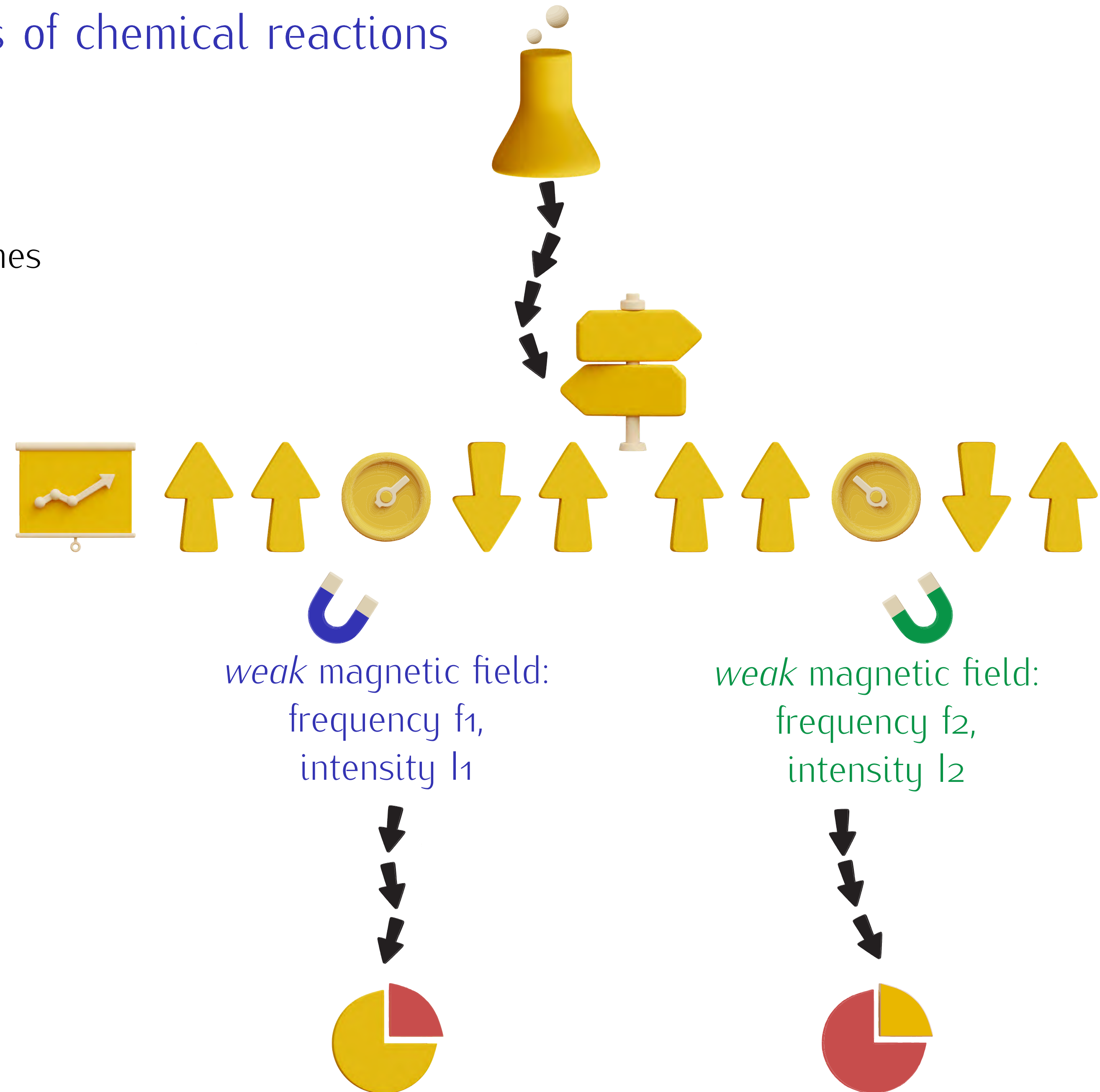


Weak magnetic fields can alter the final products of chemical reactions that are electron spin-sensitive



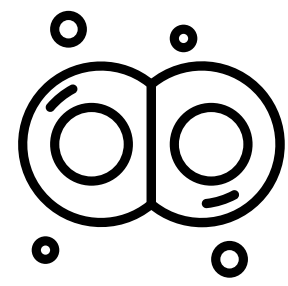
Weak magnetic fields can alter the final products of chemical reactions that are electron spin-sensitive

1. macroscopic consequences at timescales \gg coherence times
2. only *weak* fields \approx strength of hyperfine interactions
3. superposition as a resource: *bona fide* quantum sensing

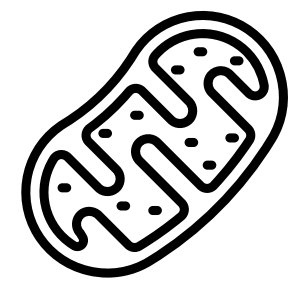


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consistent with electron spin-dependent chemical reactions

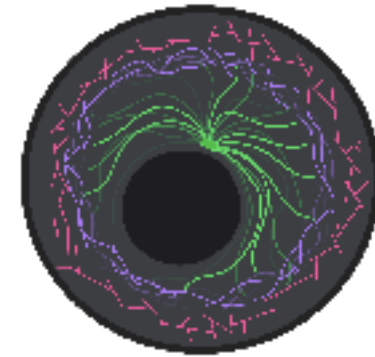
weak magnetic fields (\approx cell phone strength!) can up- and down-regulate, among others:



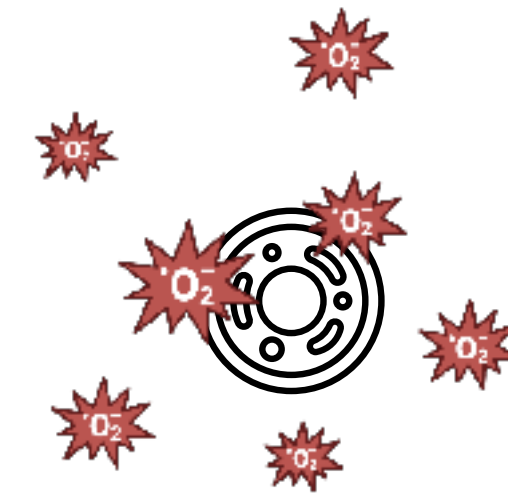
cell proliferation



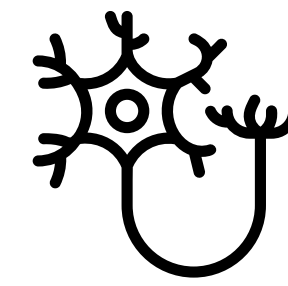
respiration
& metabolism



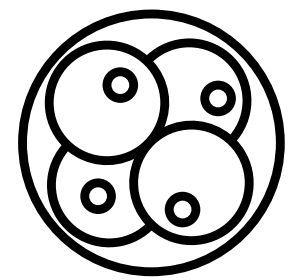
migration
& cytoskeleton



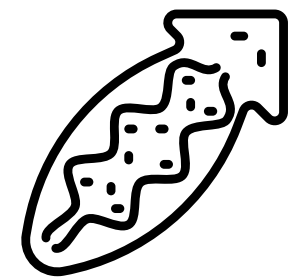
oxidative stress



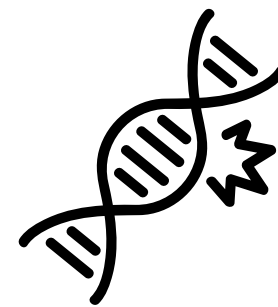
ion channel
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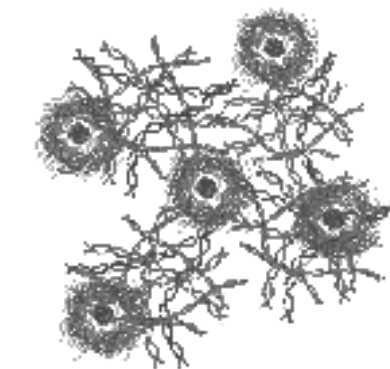
regeneration
& differentiation



DNA repair
& methylation

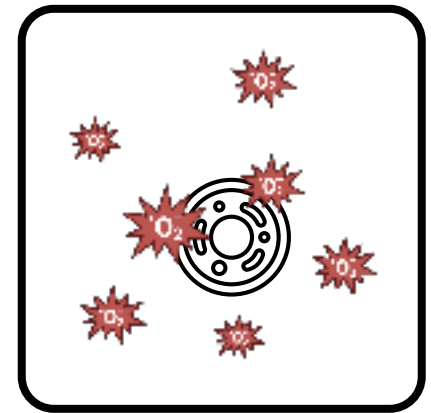


oxidative
phosphorylation



τ protein
aggregation

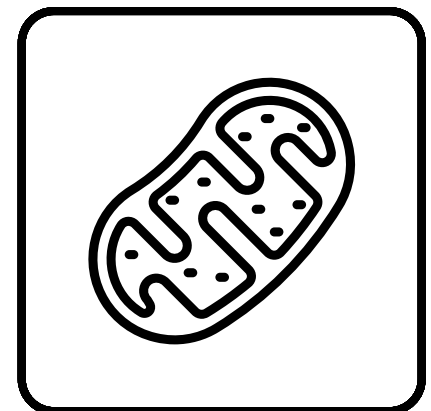
A real biological knob! Weak magnetic fields control physiology:
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The Quantum Biology of Reactive Oxygen Species Partitioning Impacts Cellular Bioenergetics

Robert J. Usselman, Cristina Chavarriga, Pablo R. Castello, Maria Procopio, Thorsten Ritz, Edward A. Dratz, David J. Singel & Carlos F. Martino

Scientific Reports 6, Article number: 38543 (2016) | Cite this article



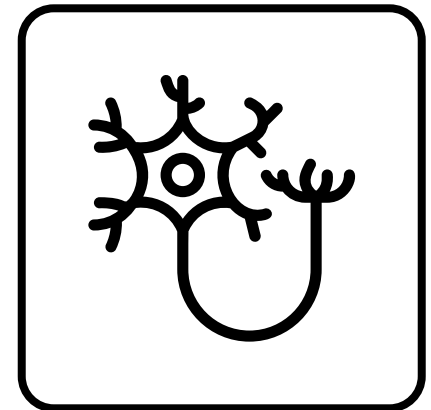
ANNALS OF THE NEW YORK ACADEMY OF SCIENCES
 Special Issue: Annals Reports

Original Article

Effects of electromagnetic fields on neuronal ion channels: a systematic review

Federico Bertagna,^{1,2} Rebecca Lewis,^{1,2} S. Ravi P. Silva,^{1,3} Johnjoe McFadden,^{1,4} and Kamalan Jeevaratnam^{1,2}

¹Leverhulme Quantum Biology Doctoral Training Centre, University of Surrey, Guildford, Surrey, UK. ²School of Veterinary Medicine, Faculty of Health and Medical Sciences, University of Surrey, Guildford, Surrey, UK. ³Advanced Technology Institute, University of Surrey, Guildford, Surrey, UK. ⁴School of Biosciences and Medicine, Faculty of Health and Medical Sciences, University of Surrey, Guildford, Surrey, UK

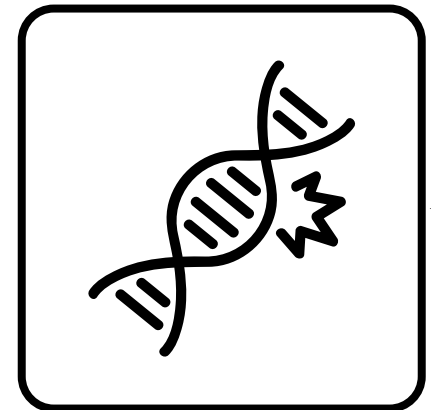


A Compass at Weak Magnetic Fields Using Thymine Dimer Repair

Theodore J. Zwang, Edmund C. M. Tse, Dongping Zhong, and Jacqueline K. Barton*

Cite this: ACS Cent. Sci. 2018, 4, 3, 405–412
 Publication Date: March 7, 2018
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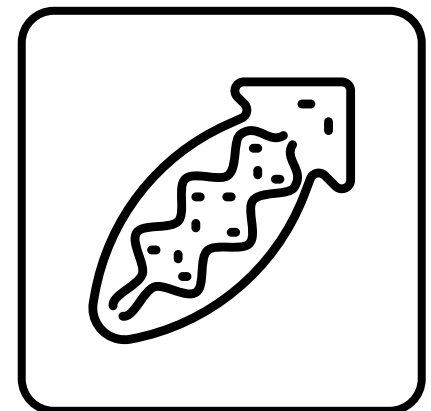


Weak magnetic fields alter stem cell-mediated growth

ALANNA V. VAN HUIZEN, JACOB M. MORTON, LUKE J. KINSEY, DONALD G. VON KANNON, MARWA A. SAAD, TAYLOR R. BIRKHOLZ, JORDAN M. CZAJKA

JULIAN CYRUS, FRANK S. BARNES, AND WENDY S. BEANE

SCIENCE ADVANCES • 30 Jan 2019 • Vol 5, Issue 1 • DOI: 10.1126/sciadv.aau7201



Chemiexcitation and melanin in photoreceptor disc turnover and prevention of macular degeneration

Yanan Lyu, Alexander V. Tschulakov, Kun Wang, and Ulrich Schraermeyer

Edited by Paul S. Bernstein, University of Utah Hospital, Salt Lake City, UT; received October 5, 2022; accepted April 3, 2023 by Editorial Board Member Jeremy Nathans

May 8, 2023 | 120 (20) e2216935120 | <https://doi.org/10.1073/pnas.2216935120>

Cellular autofluorescence is magnetic field sensitive

Noboru Ikeya and Jonathan R. Woodward

Edited by P. J. Hore, Oxford University, Oxford, United Kingdom, and accepted by Editorial Board Member Yale E. Goldman December 1, 2020 (received for review August 26, 2020)

January 4, 2021 | 118 (3) e2018043118 | <https://doi.org/10.1073/pnas.2018043118>

Essential elements of radical pair magnetosensitivity in Drosophila

Adam A. Bradlaugh, Giorgio Fedele, Anna L. Munro, Celia Napier Hansen, John M. Hares, Sanjai Patel, Charalambos P. Kyriacou, Alex R. Jones, Ezio Rosato & Richard A. Baines

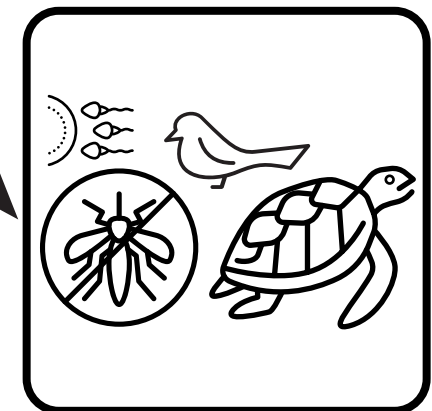
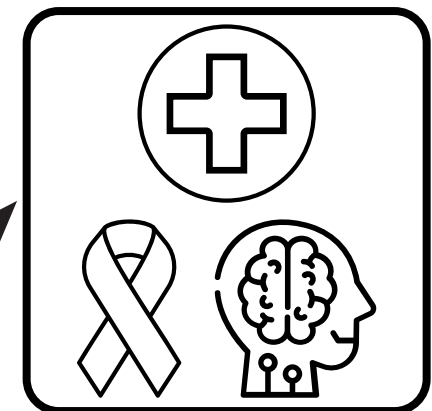
Nature 615, 111–116 (2023) | Cite this article

Magnetic sensitivity of cryptochrome 4 from a migratory songbird

Jingjing Xu, Lauren E. Jarocha, Tilo Zollitsch, Marcin Konowalczyk, Kevin B. Henbest, Sabine Richert, Matthew J. Golesworthy, Jessica Schmidt, Victoire Déjean, Daniel J. C. Sowood, Marco Bassetto, Jiate Luo, Jessica R. Walton, Jessica Fleming, Yujing Wei, Tommy L. Pitcher, Gabriel Moise, Maike Herrmann, Hang Yin, Haijia Wu, Rabea Bartölke, Stefanie J. Käsehagen, Simon Horst, Glen Dautaj, ... P. J. Hore

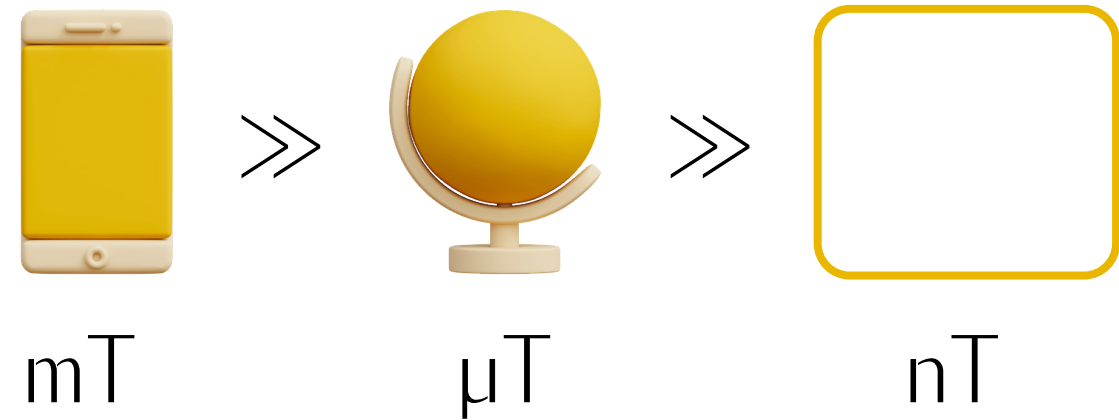
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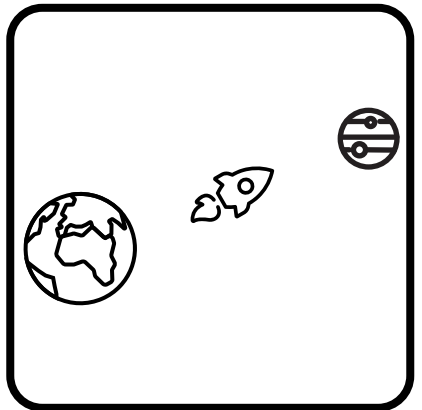
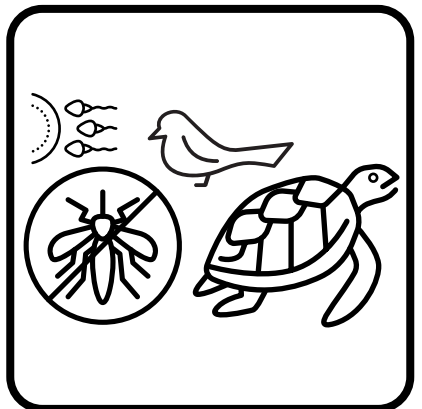
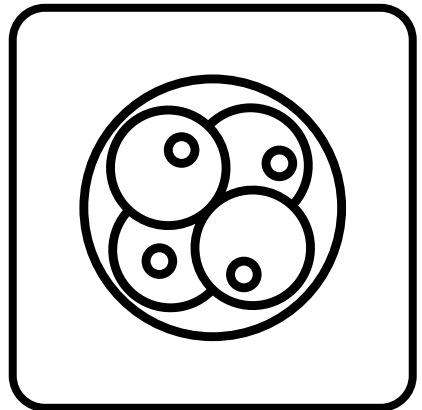


A real biological knob! Weak magnetic fields control physiology:
40+ years of widespread, organism- and cell type-agnostic correlative data
consistent with electron spin-dependent chemical reactions

passive shielding can already induce effects:
removing Earth's weak field

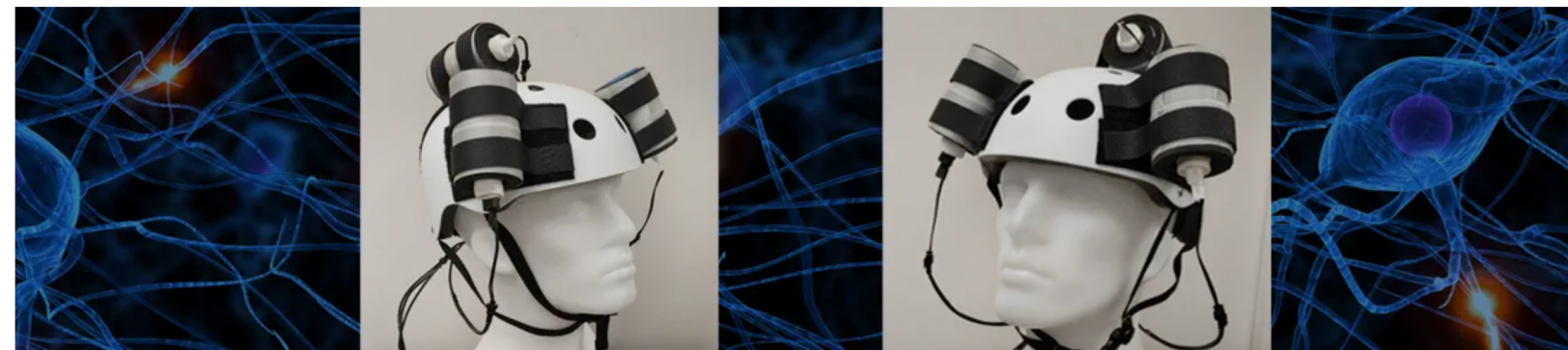
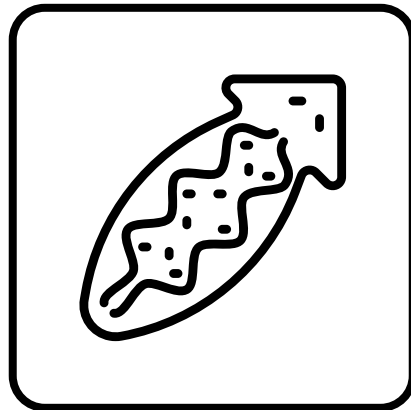
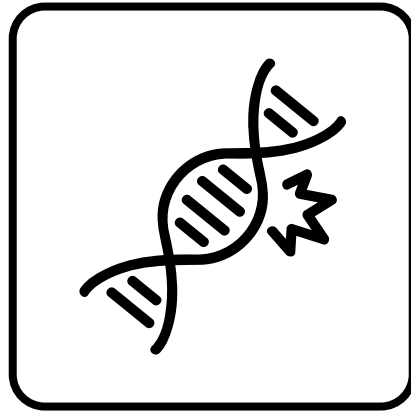
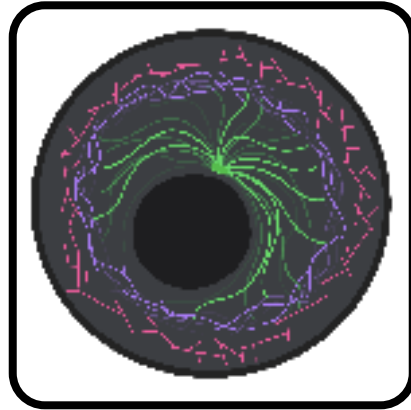
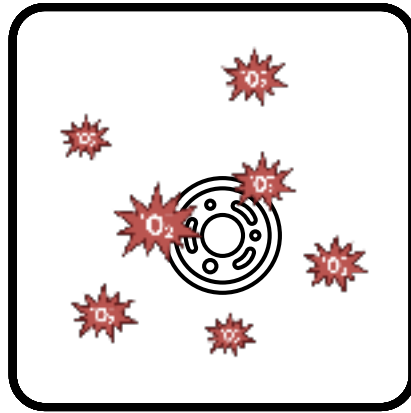
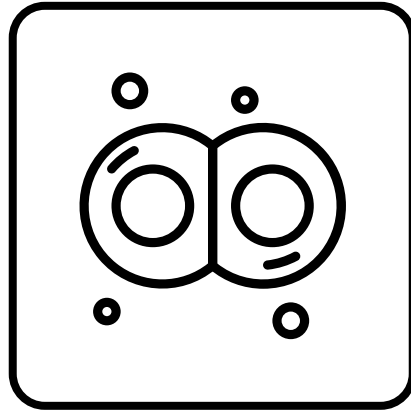


hypomagnetic chamber



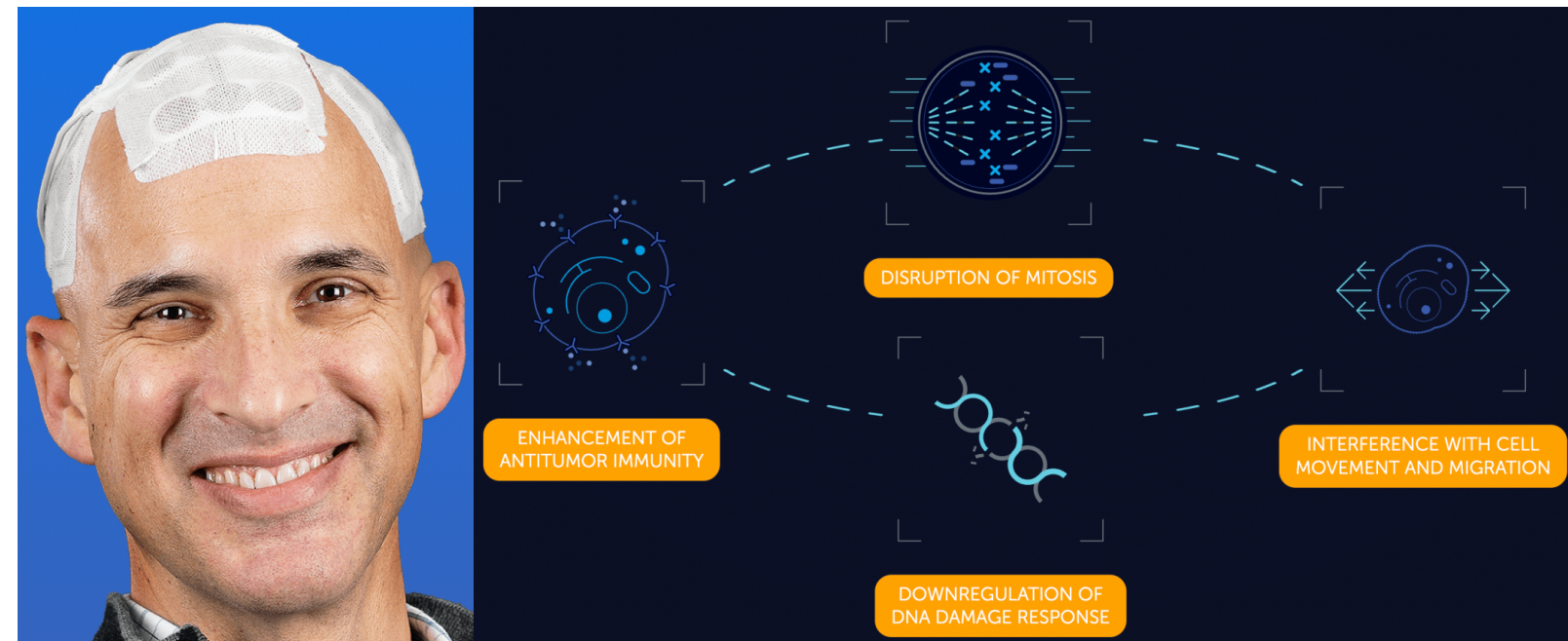
data credit: Prof. Peter Fierlinger, TU München (in preparation for publication)

Correlative data
consistent with electron spin-dependent chemical reactions
 is already being harnessed



CANCER, NEUROLOGY & NEUROSURGERY

Magnetic Device Shrinks Glioblastoma Tumor in World's First Human Test



OncoFTX Breast Cancer Coil System

1 Background
 Breast cancer is the leading cause of cancer-associated death for women worldwide. 1 in 8 women have a chance of being diagnosed with invasive breast cancer during their lifetime.

2 The coil system
 The OncoFTX breast cancer coil system uses mitochondrial pulsed electromagnetic field therapy (PEMF) to produce detrimental levels of oxidative stress that can kill cancer cells. The coil system targets a specific body region afflicted with cancer for a localised, non-invasive and painless treatment.

3 How it works (in detail)
 PEMF exposure enhances reactive oxygen species (ROS) by stimulating mitochondrial respiration via targeting the TRPC1 calcium ion channel. Overstimulation of the TRPC1-mitochondrial axis exaggerates ROS production, which overwhelms a cell's existing antioxidant defences to induce cancer cell killing. Elevations of TRPC1 expression are common in breast cancers.

4 Conventional therapy
 Chemotherapy is the mainstream treatment for breast cancer. Chemotherapy works by halting cell division, causing the cancer cells to die and tumour to shrink. Unfortunately, chemotherapy works systemically and does not differentiate between cancer and normal cells. All dividing cells are compromised and experience negative effects.

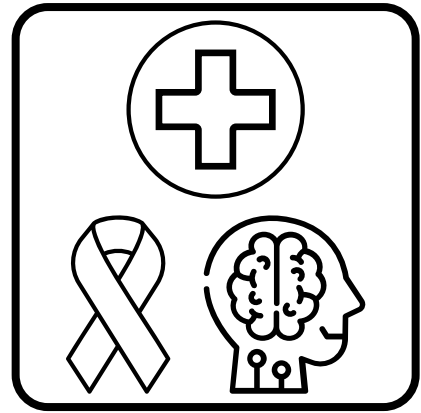
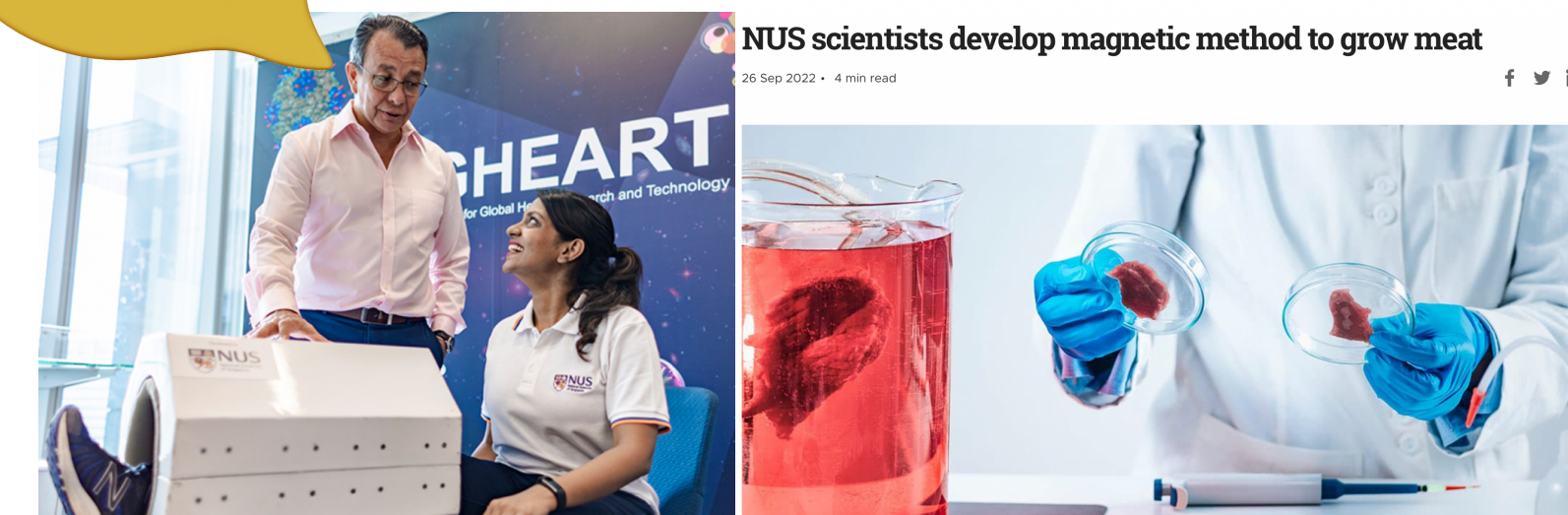
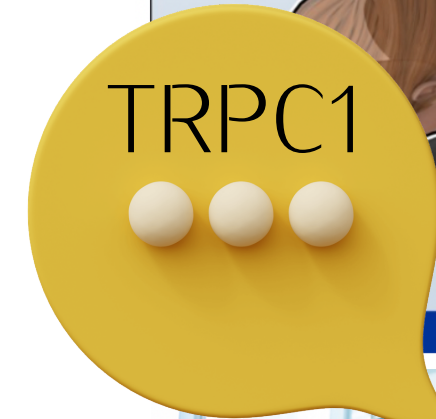
5 Potential application
 Magnetic therapy offers an advantage as an effective companion therapy to chemotherapy for treatment of breast cancers characterised by elevated TRPC1 expression levels, potentially allowing for the lowering of systemically-delivered chemotherapeutic dosage and reducing chemotherapy-related adverse events.

1 in 8

50% chance of adverse events

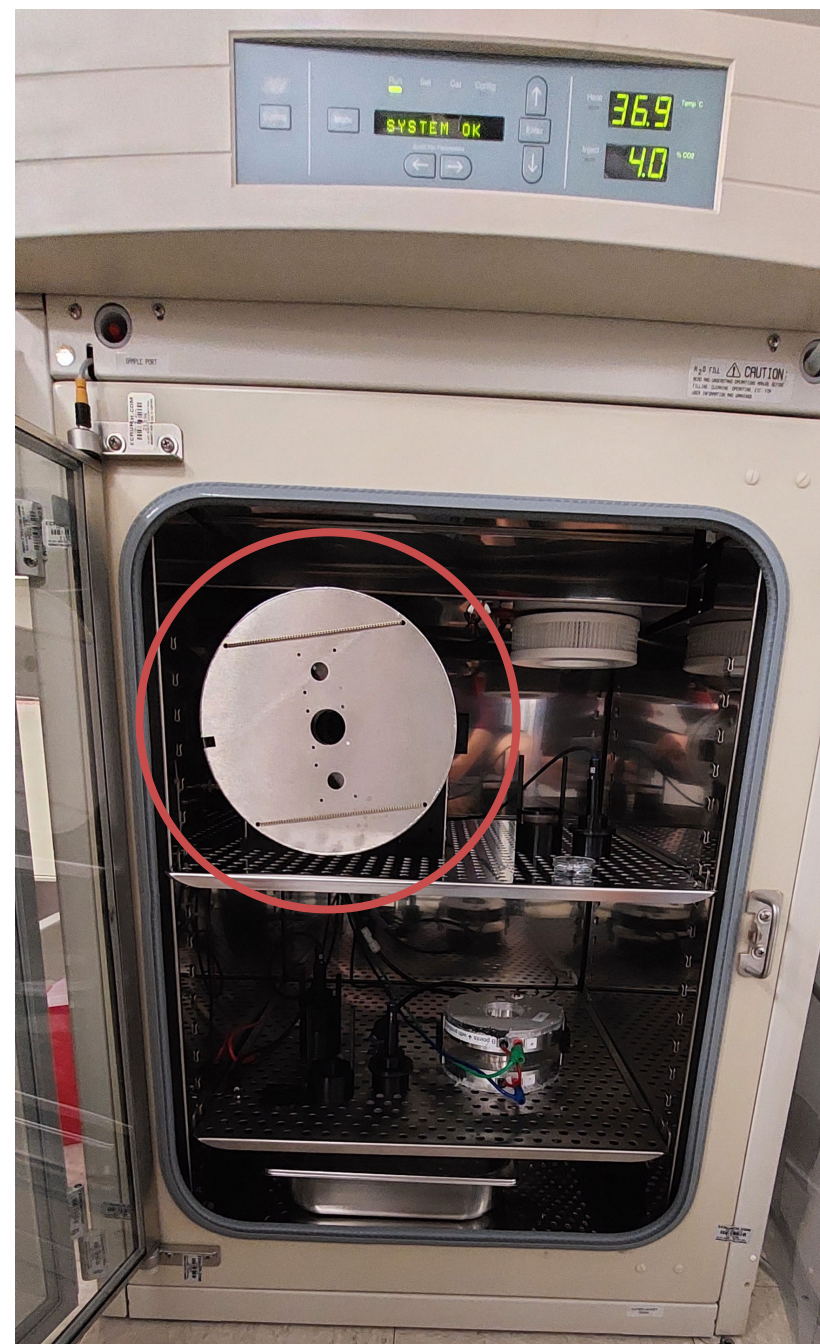
TRPC1

National University of Singapore



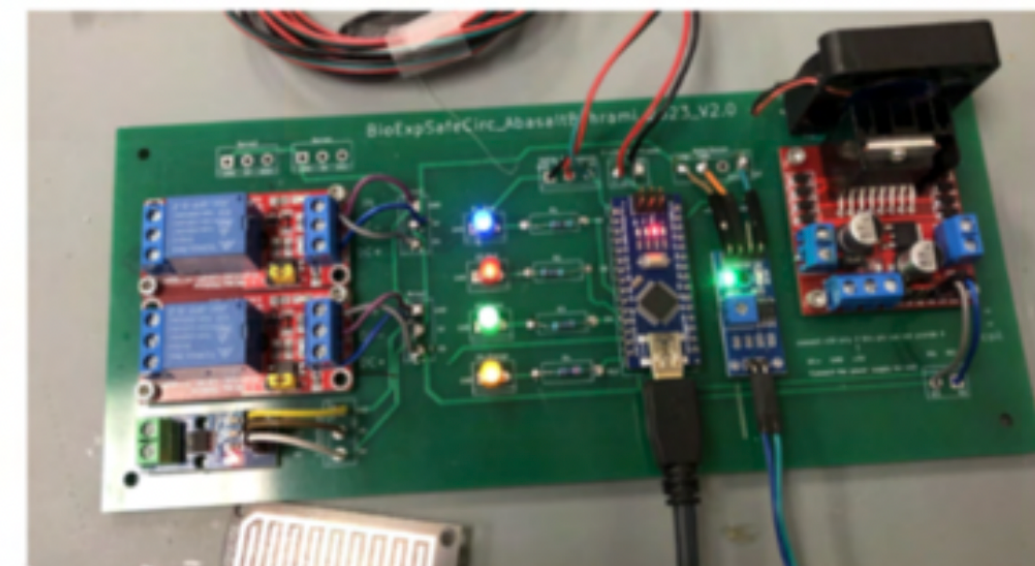
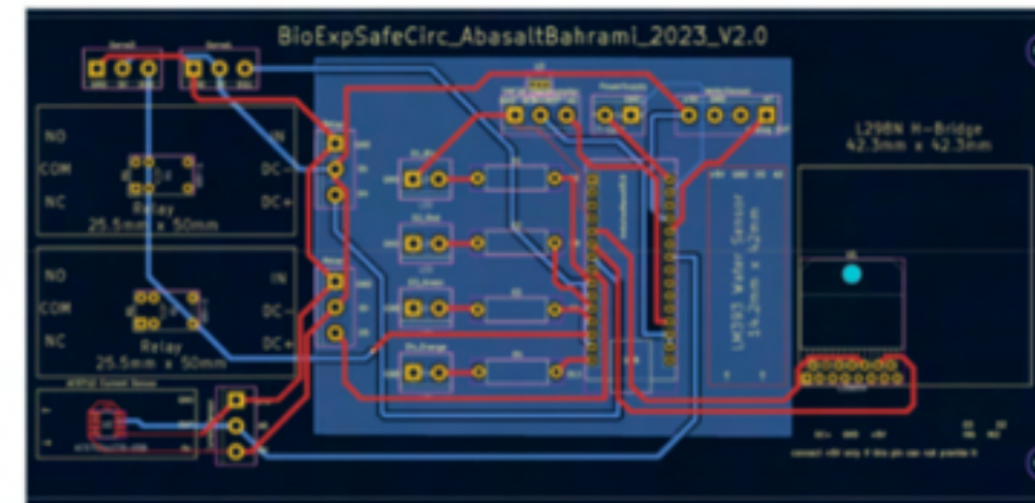
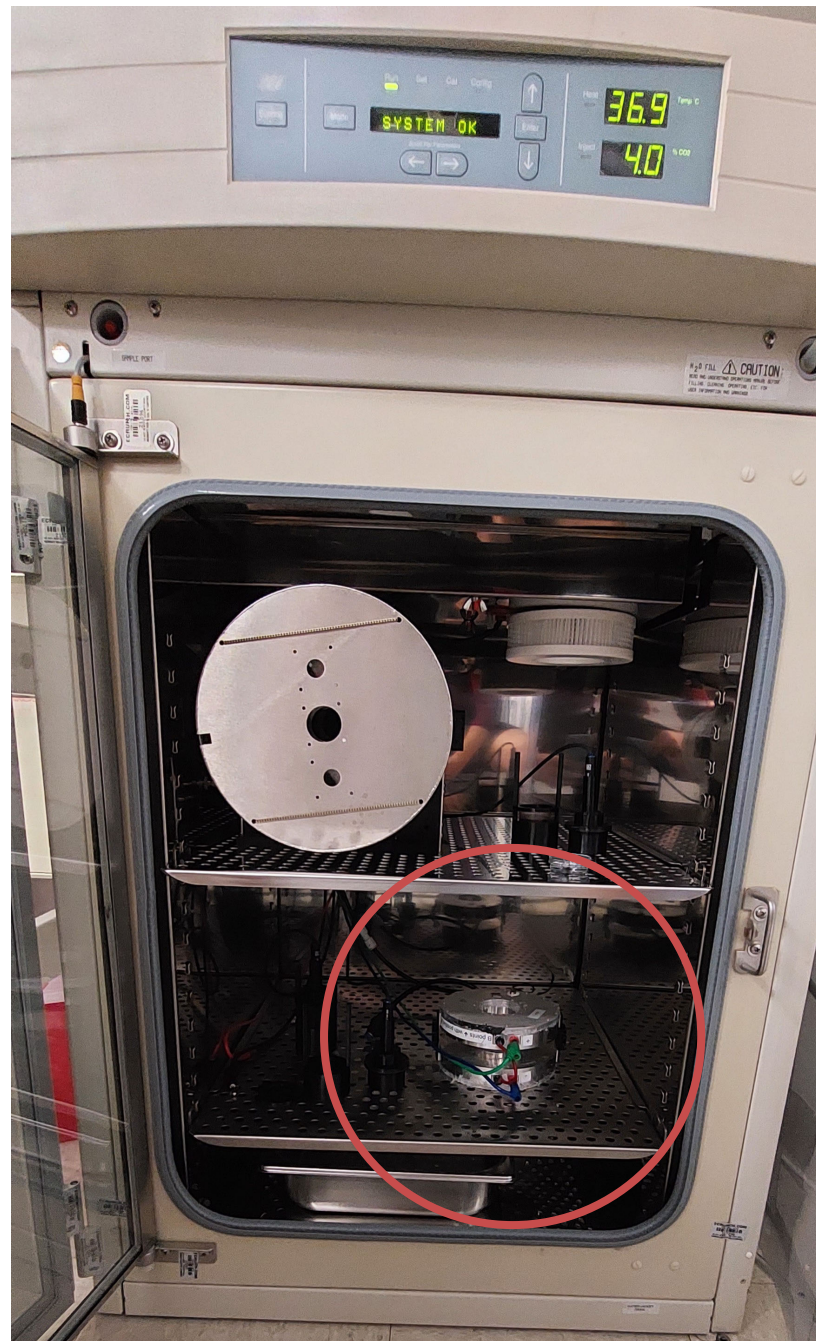
Where we're at: short-term:
more, *better* correlative data of weak magnetic field effect in cells

commercial hypomagnetic chamber inside incubator



Where we're at: short-term:
more, *better* correlative data of weak magnetic field effect in cells

fully automated coils inside incubator:
raster fields up to 30 mT (div. $< 10 \mu\text{T}$ over dish);
raster field frequencies up to 50 Hz;
hands-free rotation;
water cooled (thermal effects $< 0.1 \text{ }^\circ\text{C}$ at max. current)



Where we're at: short-term:
0.5x your cell phone speaker's field alters cellular morphology

reproducible, being quantified

actin

mitochondria

microtubules

muscle

4 h

Alexa Fluor 546

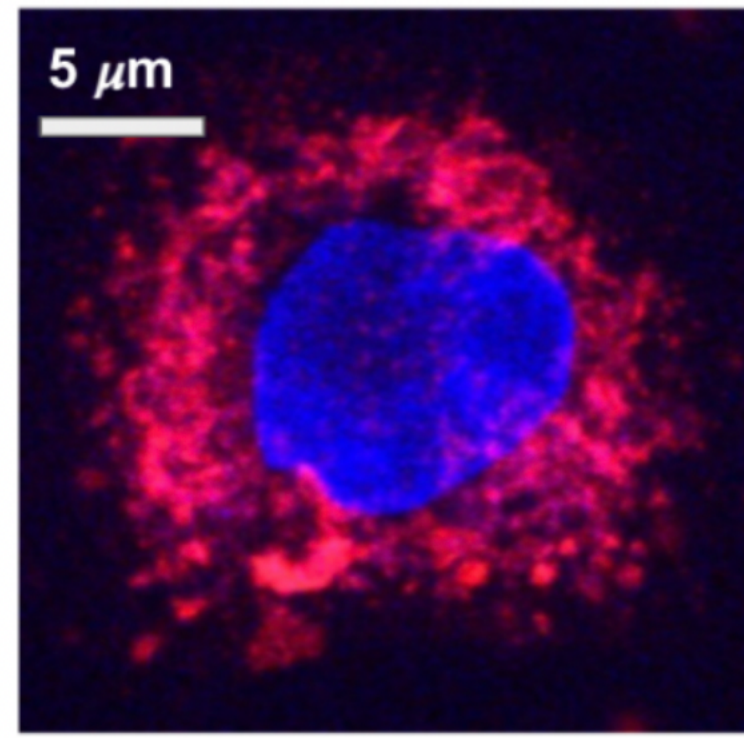
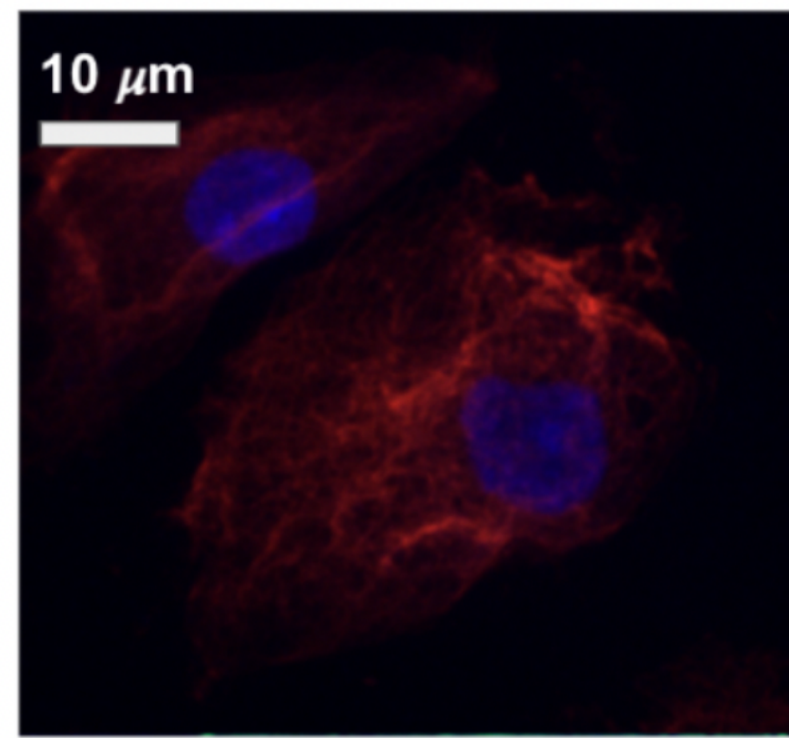
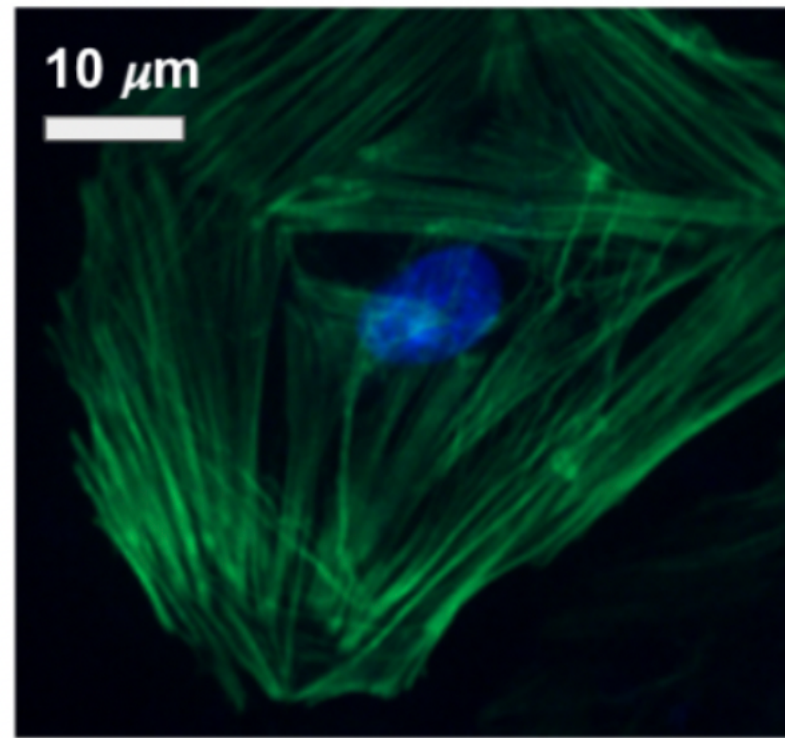
4 h

MitoTracker

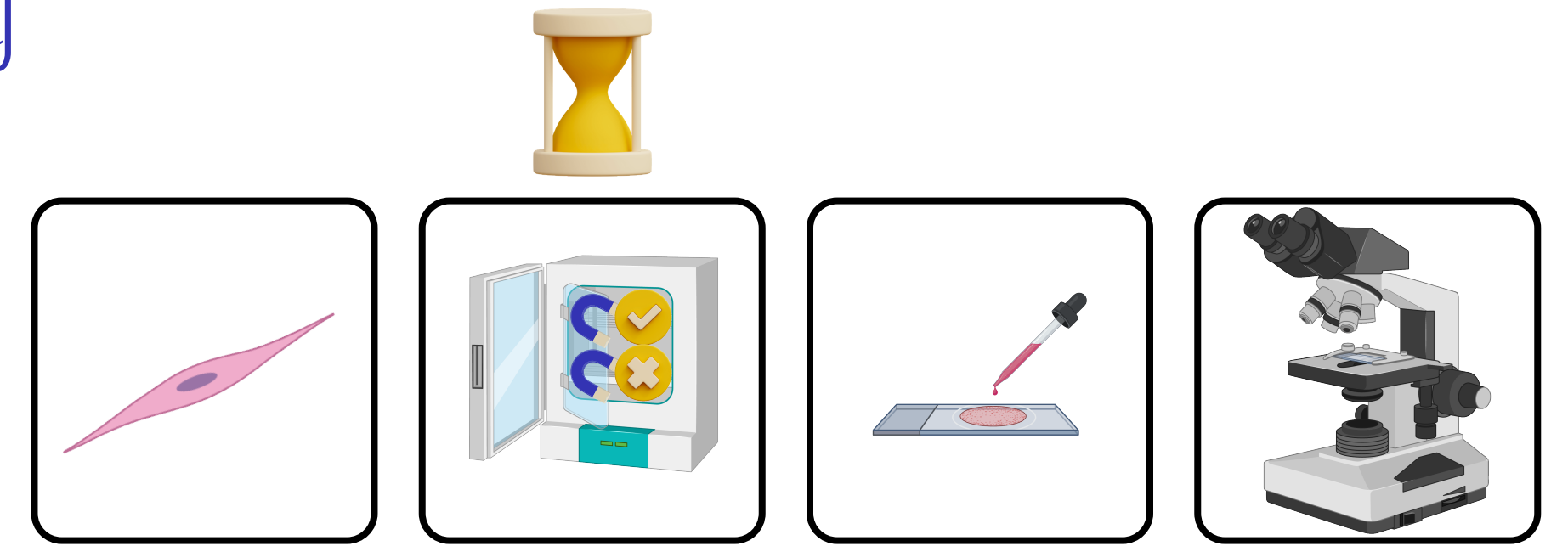
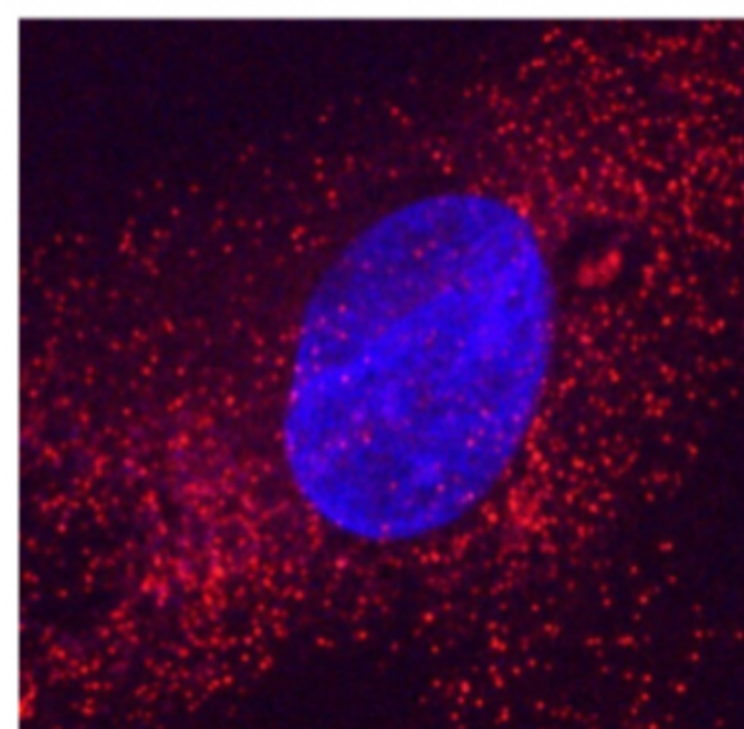
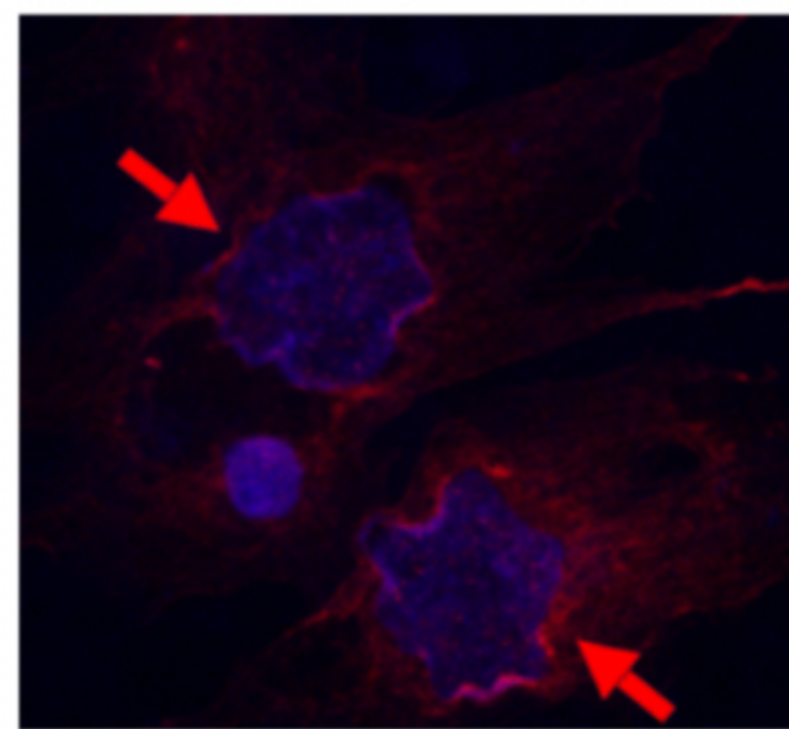
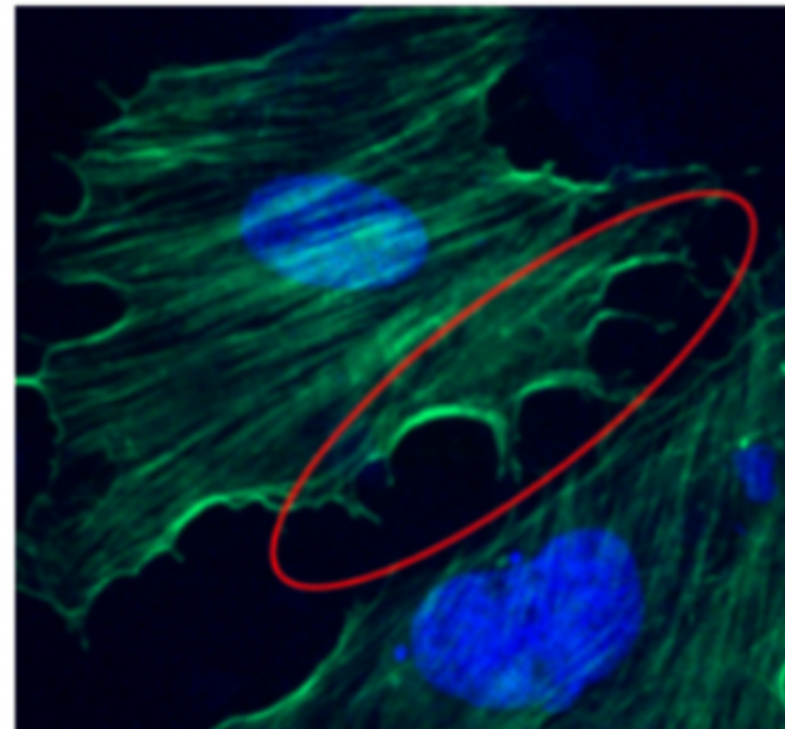
68 h

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controls

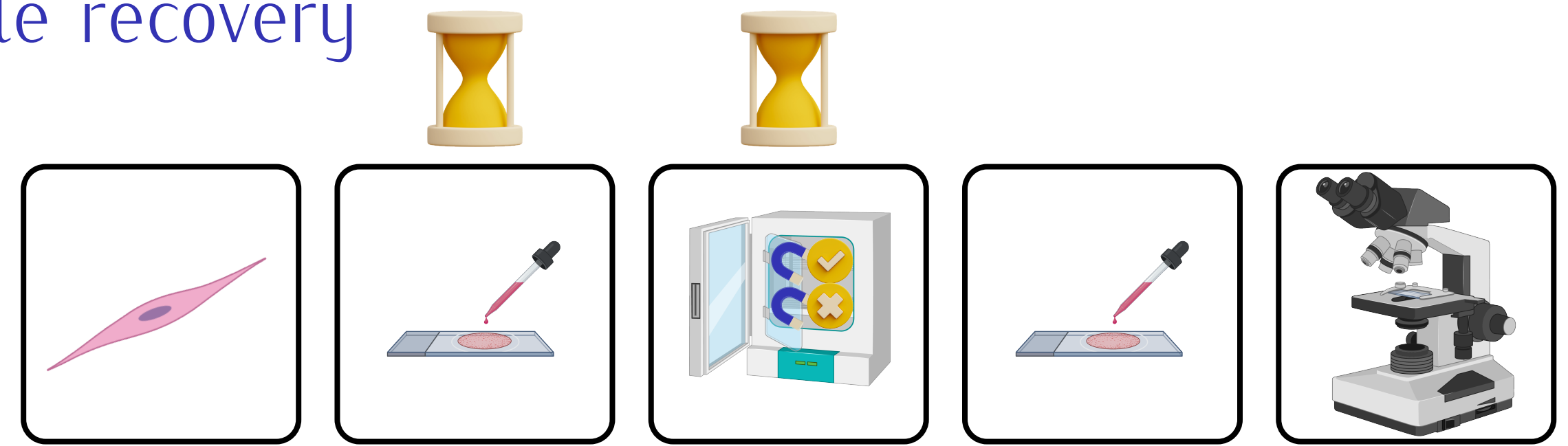


exposed to
0.5 mT



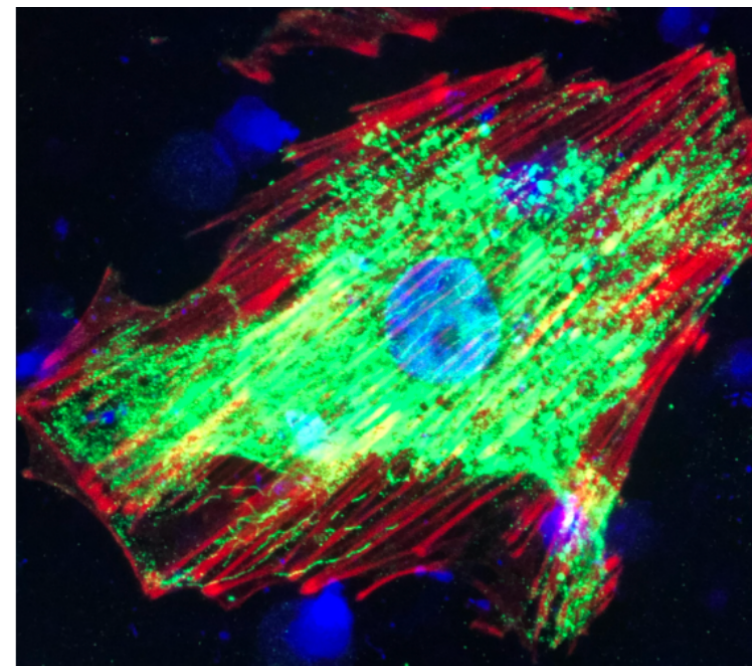
Where we're at: short-term:
0.5x your cell phone speaker's field alters microtubule recovery

reproducible, being quantified

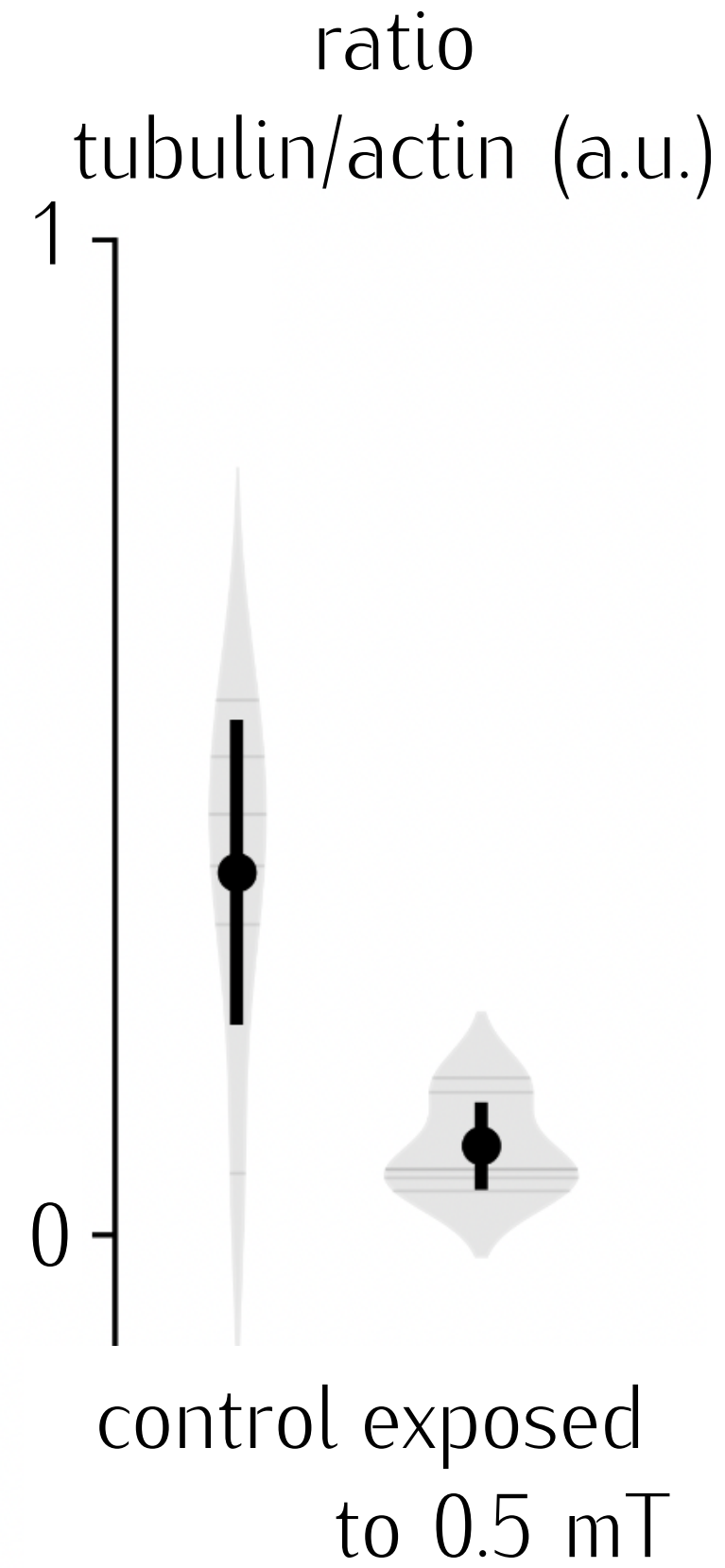
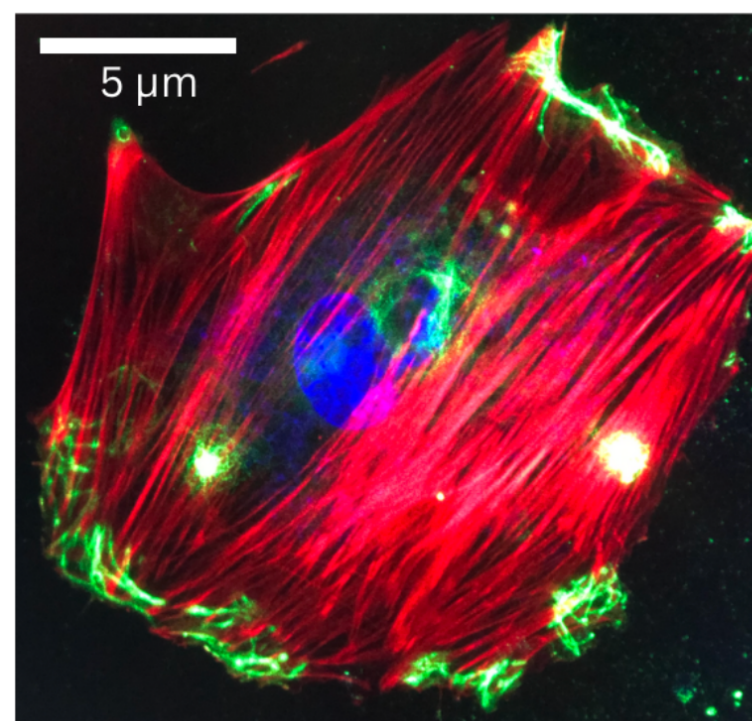


actin
microtubules

control



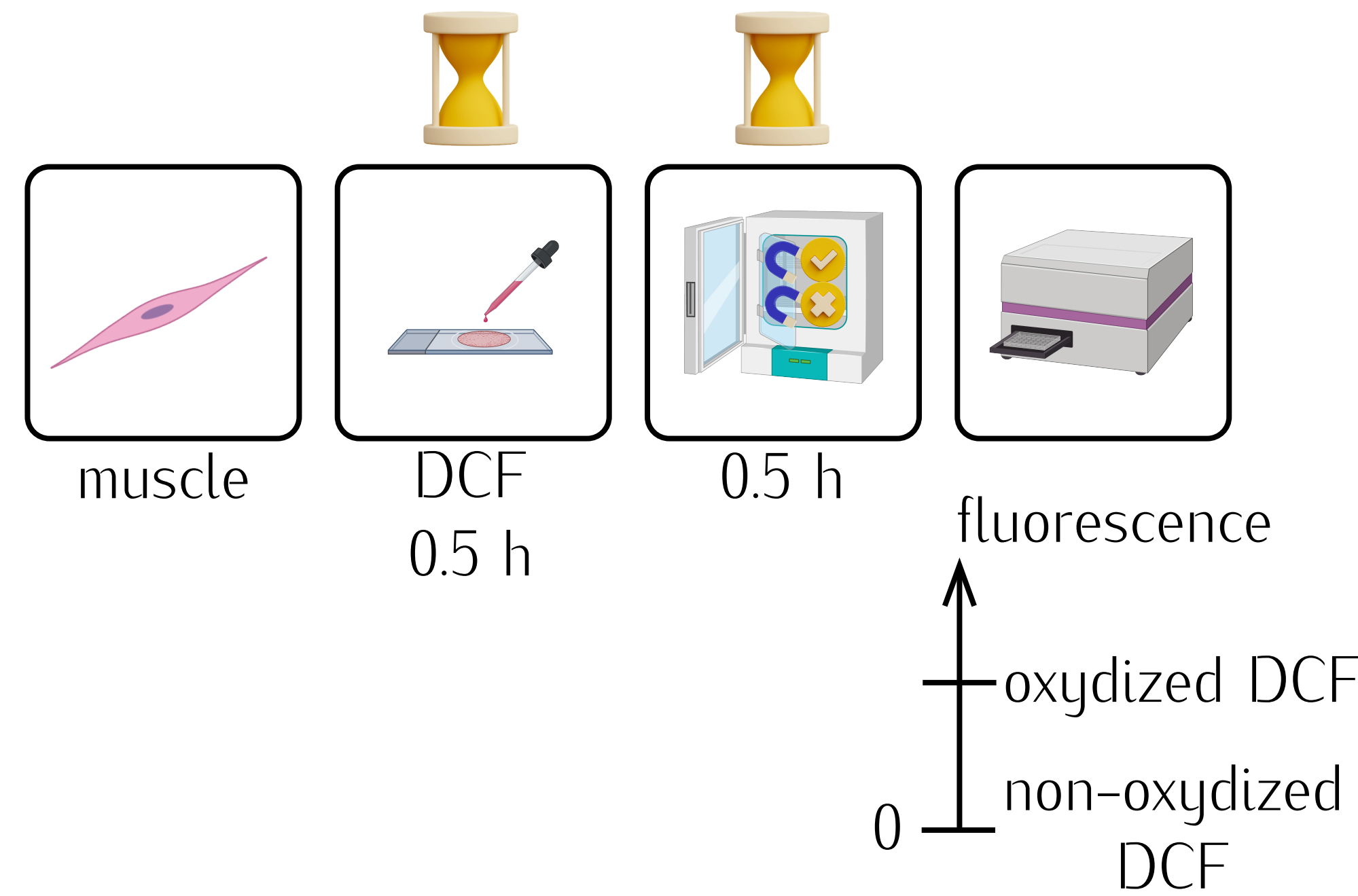
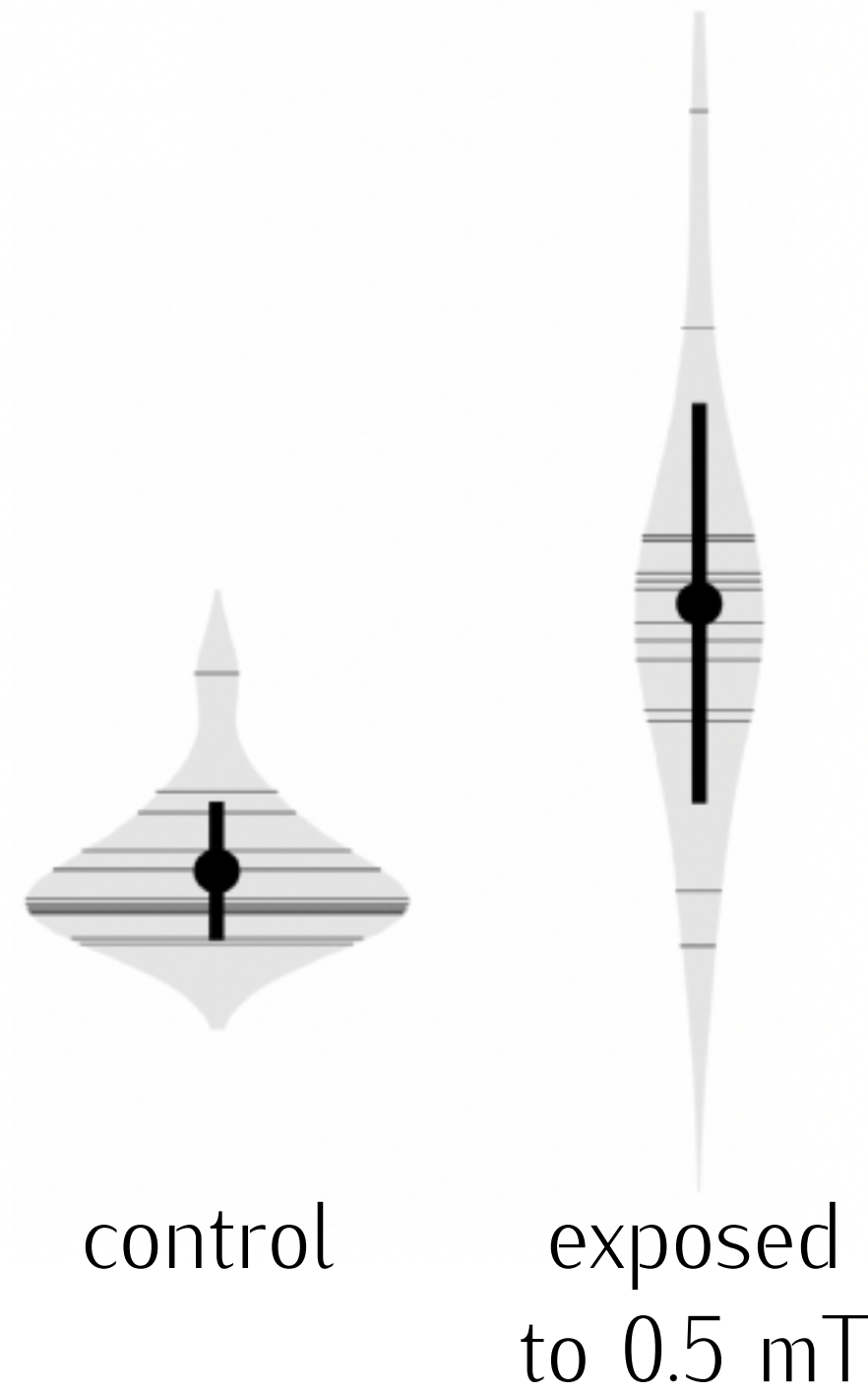
exposed to
0.5 mT



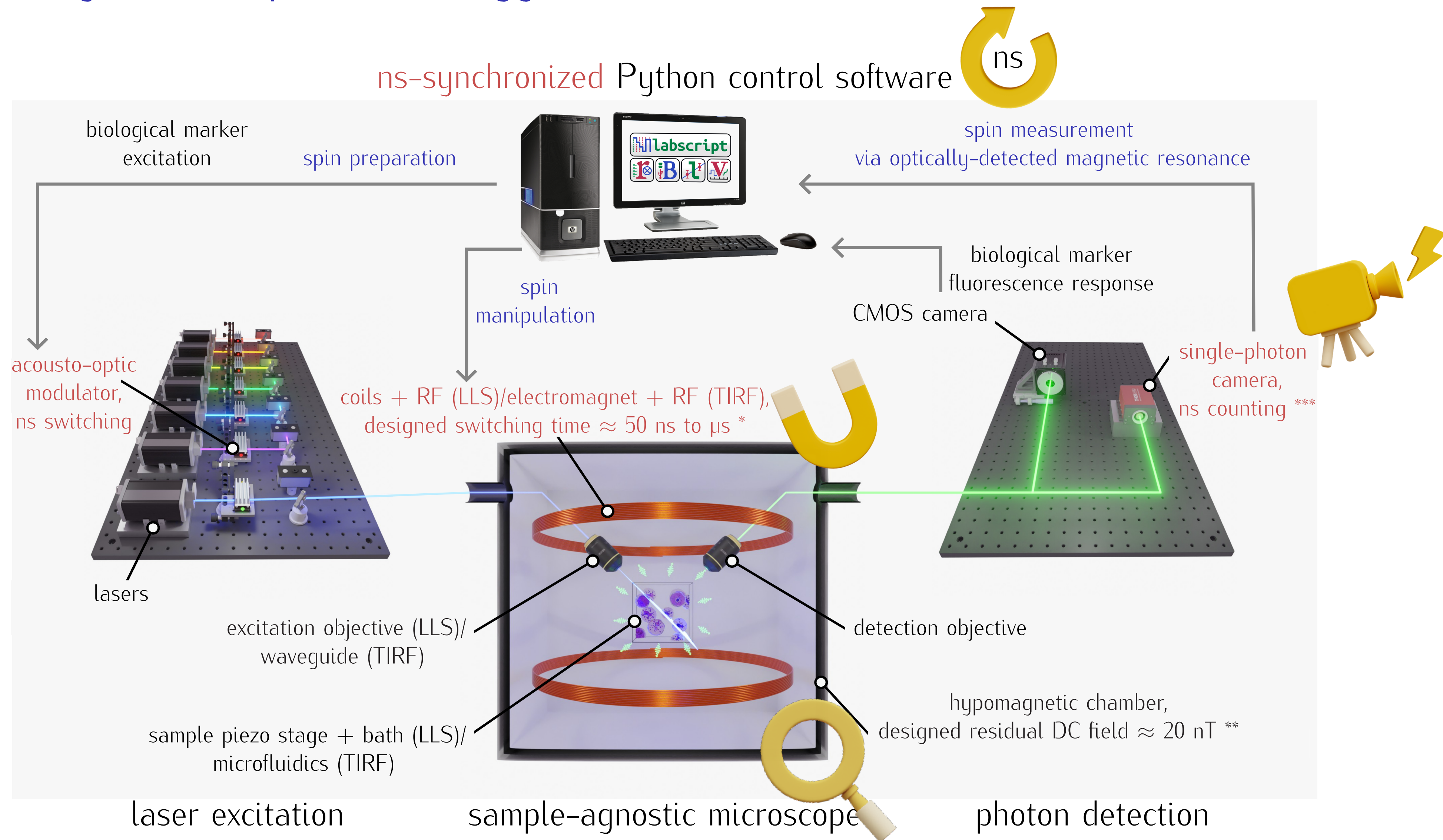
Where we're at: short-term:
0.5x your cell phone speaker's field alters overall ROS levels
for short exposure times

not yet reproduced

DCF fluorescence (a.u.) \propto ROS



Where we're at: long-term:
to deterministically control spins in biology for function



* design credit: Rev. Scient. Instr. 78, 036104 (2007): 20 mT in 50 ns! ** with Prof. Peter Fierlinger, TU München; *** with Prof. Edoardo Charbon, EPFL

Where we're at: long-term: *to deterministically control spins in biology for function*

scientific goals:

to establish the extent to which spins are harnessed by biology
&
to rationally drive spin-dependent processes in biology
with the following quantum instruments:

1. optical microscopes (TIRF & LLS) with coils
2. electrophysiology microscope with coils
3. scanning tunneling microscope with coils (a.k.a. "ESR-STM")

technological goal:

to develop
endogenous, non-chemical, non-invasive, cheap, remotely-actuated, portable
electromagnetic interventions informing a myriad of fields

