NANOMAGNETIC ACTUATORS FOR NEUROMODULATION

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Stimulation of cell signaling and differentiation


Controlled drug delivery

• Rodgers T., et al., Bioengineering, 2021, 8, 16.
Bioelectronics
Emerging area of medicine that uses miniaturized implantable devices to deliver electrical stimulation to nerves to control wide range of bodily functions

Electroceuticals
Type of bioelectronics aimed at replacing pharmaceutical therapy

• Represents a multimillion-dollar opportunity with $15,000 million dollars market in 2020 and expected to grow to $23,000 million dollars by 2026

• Medtronic, Roche, Siemens AG, Abbott, Honeywell International, Beckman Coulter, Life Sensors, Bioelectronic Corporation, Avago, Omnivision Technologies, Sotera Wireless, etc.
Deep Brain Stimulation (DBS)

- Mechanically invasive
- Non-specific cell type
- Surgical and electrochemical complications
- Unknown molecular mechanism

- Magnetic fields interact weakly with tissue due to low magnetic susceptibility
- Magnetic nanoparticles work as transducers of magnetic fields

http://www.treatment4addiction.com/drugs/society/teen-brain/
Synthetic magnetic nanomaterials coupled to channel proteins, which respond to stimuli (heat, mechanical strain, electric fields, and chemical interactions). In response, the channel proteins open allowing influx of ions, such as Ca\(^{2+}\) or Na\(^{+}\), triggering action potentials in neurons.

**Thermal cues**

**Chemical cues**

**Mechanical cues**
Synthetic **magnetic nanomaterials coupled to channel proteins**, which respond to stimuli (*heat, mechanical strain, electric fields, and chemical interactions*). In response, the channel proteins open allowing influx of ions, such as Ca$^{2+}$ or Na$^+$, **triggering action potentials in neurons**.

**MAGNETIC HYPERTHERMIA CONCERNS**

1. Potential **off-target heating** effects
2. Challenges in scaling **high-frequency AMFs** coils impede universal adoption of magnetic hyperthermia in biomedical research.
Polymeric Nanoactuators

Electric cues for stimulation of activity and growth

Biomimetic synthesized conductive copolymer 3,4-ethylenedioxythiophene (EDOT)-Pyrrole nanoparticles

- Pseudocapacitive behavior
- Good Conductivity
- High capacitance

Control  
CCP-NPs  
Charged CCP-NPs

Actin Nucleus

150 µm  500 nm
Imagine a world where we treat deadly diseases with electricity instead of pills or chemo.
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Collaborators:
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Sergio Moya, CIC biomaGUNE, Spain
Marco Marradi, Università degli Studi di Firenze, Italy

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Visiting PhD students
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Cristian Salvador
Maria Regato
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THANK YOU

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