Selected topics in life sciences

Jocelyn Bloch

General Feedback on the lecture

I found Jocelyn to be an excellent lecturer and a remarkable woman. The research she has done is so groundbreaking and changes peoples life for the better. I think I can speak for the full class that we have a lot of respect for her.

Her way of explaining things was very clear and calm, making it easy for everyone to grasp the topic. She was open to questions throughout, which created a welcoming environment. Despite most of us being new to the subject, she avoided diving too deeply into theoretical aspects, ensuring we could all follow along. After the lecture, I definitely felt more informed about this new topic. However, it might have been beneficial for her to explore the technical aspects further, especially for those with prior knowledge. Her presentation slides were well-organized, incorporating lots of visuals like photos and videos from her research.

Take home messages from the lecture

- DBS improves quality of life: DBS doesn't 'cure' the disease itself but significantly improves the quality of life for individuals with movement disorders by reducing motor fluctuations.
- Gene Therapy as possible solution: Gene therapy offers a potential method to shield neurons from further degeneration, presenting a promising approach for fighting movement disorders.
- Neurosurgeons love engineers: The collaboration between neurosurgeons and engineers plays a main role in advancing treatments. Especially in the field of imaging, mechanics and robotics.
- Neuromodulation: DBS helps with movement problems in Parkinson's. By using frequent and prolonged stimulation, it calms down excessive activity in the brain. To do this well, we need precise technology like robotics and advanced imaging
- Locomoteurs: Epidural electrical stimulation shows promise in bridging signal gaps in gait disorders post-spinal cord injury. Biomimetic stimulation targeting specific spinal cord hotspots, along with personalized programming, revolutionizes rehabilitation strategies, minimizing dependency on physiotherapists for stimulation adjustments.

Identify and describe a recent publication that illustrates recent advances in using neuroprosthetics, implantable neurotechnologies or neurostimulation to restore function that has been lost due to spinal cord injury or treat specific medical conditions

Paper: 'Neurostimulation for Stroke Rehabilitation'

Summary:

The research delves into the topic of neuroplasticity (how the brain can learn to regain movement after a stroke by 'rewiring' itself). Usual therapies might not always work sufficiently, so there is a large need for techniques to assist this rewiring process. One of these techniques is neurostimulation, particularly closed-loop systems and optogenetics, to induce more precise and targeted neural reorganization. The researchers plead for advancing research into plasticity principles to revolutionize rehabilitation and help more people recover from brain injuries.

Why?:

Stroke is ranked as the second leading cause of death worldwide with an annual mortality rate of about 5.5 million. Not only does the burden of stroke lie in the high mortality but the high morbidity also results in up to 50% of survivors being chronically disabled [1].

These numbers sound horrifying to me and show that stroke is a disease of immense public health importance with serious economic and social consequences. In addition, I recently read an article saying that the prevalence of strokes is only growing. As this disease is something that every person probably will encounter for themselves or their loved ones, I found knew I wanted to choose an article talking about new methods to treat patients who suffered a stroke.

The paper addresses innovative methodologies to battle this problem. It combines medicine and engineering, which for me as an engineer is always interesting to look into.

Take home messages:

- Despite conventional therapies, post-stroke recovery remains slow and incomplete due to limited neural reorganization.
- Precise neurostimulation methods like closed-loop systems and optogenetics show promise in inducing targeted neural changes for improved recovery.
- More focused stimulation techniques could enhance neural plasticity, especially closed-loop systems and optogenetics, aiding functional brain reorganization.
- Integrating closed-loop systems and optogenetics, alongside understanding plasticity principles, may revolutionize post-stroke recovery and neuroscience rehabilitation.

Questions on Topics covered in the lecture

Answers based on paper 'A spinal cord neuroprosthesis for locomotor deficits due to Parkinson's disease' [2]

- *Using words and schematic depictions explain the main conceptual and technological advances that enabled Prof. Bloch and colleagues to develop treatments that allowed their Parkinson's patient to walk again.*

  Instead of focusing only on the brain, they targeted the lumbosacral spinal cord. This area is responsible for generating walking motions and isn't directly affected by Parkinson's disease (PD). Targeted epidural electrical stimulation (EES) of the lumbosacral spinal cord influences the activity of motor neurons by activating large-diameter afferents [2]. This allows for real-time control over leg motor neurons and muscles. The technique targets so called 'hotspots' in the spinal cord by precisely timing the stimulation to mimic how the body normally activates leg muscles (=biomimetic stimulation). It has successfully helped paralyzed individuals regain the ability to stand, walk, cycle, and even swim [2].

- *What specific symptoms of Parkinson's disease does this therapy aim to treat and what measure did the investigators take to optimize this treatment to the specific needs of their patient?*

  The specific symptoms treated are locomotor deficits, which include gait impairments, balance problems and freezing-of-gait episodes [2].

  Personalized programmation with tailored implanted electrodes, these tell what places are best to stimulate and delivers a personalized stimulation. They generated a personalized neurobiomechanical model47 actuated by a reflex-based circuit that allowed us to estimate the optimal activation of muscles during walking that was expected by P1 in the absence of PD [2].

- *Describe some of the main limitations of this approach*

  The neuroprosthesis was tested on a small scale, primarily in non-human primates (NHPs) and validated in only one person with Parkinson's disease (PD). The effectiveness across a broader spectrum of PD patients remains uncertain. Moreover, parkinson's disease manifests with a wide range of symptoms and degrees of severity in locomotor deficits. It's unclear if this neuroprosthesis will effectively address these diverse issues in the entire PD population.

  Scaling up the therapy requires advanced, purpose-built technologies. This involves creating electrode arrays customized for each person's specific nerve entry zones in the spine, along with a device that controls the electrical stimulation very precisely.

  The synchronization of the neuroprosthesis with motor intentions requires the identification of the optimal tradeoff among invasiveness, reliability and practicality of the technology used to detect motor intentions [2]. Patients prefer using wearable sensors that aren't invasive, as long as they're reliable and practical for daily use.

References:

[1] Donkor ES. Stroke in the 21st Century: A Snapshot of the Burden, Epidemiology, and Quality of Life. Stroke Res Treat. 2018 Nov 27;2018:3238165. doi: 10.1155/2018/3238165
[2] Milekovic, T., Moraud, E.M., Macellari, N. et al. A spinal cord neuroprosthesis for locomotor deficits due to Parkinson's disease. Nat Med 29, 2854–2865 (2023). https://doi.org/10.1038/s41591-023-02584-1