1. **What are BCIs?**

- Brain-Computer Interfaces (BCIs) enable direct communication between the brain and external devices. They bypass traditional motor pathways, allowing neural activity to control digital systems without physical movement. This technology sits at the intersection of neuroscience, engineering, and artificial intelligence.

2. **How BCIs Work**

- BCIs function by capturing neural signals using electrodes, either non-invasive (EEG) or invasive implants placed directly in the brain. These signals are then filtered to remove noise and processed to extract meaningful patterns, such as motor intentions or speech planning.
- Machine learning algorithms decode these patterns and translate them into digital commands, which can control devices like computers, prosthetics, or communication systems in real time.

3. **Current Technology**

- Companies like Neuralink are developing implantable chips with microelectrodes that record high-resolution neural activity and transmit it wirelessly. Early human trials show patients controlling cursors and interfaces using only thought.
- In contrast, Synchron uses a minimally invasive approach by inserting devices through blood vessels, reducing surgical risk while still enabling patients to send messages and interact with digital systems.

4. **Medical Applications**

- One of the most impactful uses of BCIs is their ability to restore lost function in patients with neurological conditions.
- By interpreting signals from the motor cortex, BCIs can allow paralyzed individuals to control prosthetic limbs or assistive devices using only their thoughts.
- They can also convert brain activity related to speech into text, giving people with conditions like ALS a way to communicate even when they can no longer speak.

5. **Challenges and Future Potential**

- Although BCIs have made major progress, there are still important challenges to address.
- Neural signals can be unstable over time, and implanted devices must remain safe and reliable for long-term use.
- In addition, decoding brain activity accurately often requires large amounts of personalized data and training. Despite these limitations, advances in AI and neural engineering are rapidly improving performance, and BCIs are becoming more practical.
- In the future, they could move beyond medical use and enable more seamless interaction between humans and technology.

References

Latha, & Ramesh. (2025). A comprehensive review of AI-based brain-computer interface with prefrontal cortex and sensory-motor rhythms systemization for rehabilitation. *Results in Engineering*, *27*, 106483. https://doi.org/10.1016/j.rineng.2025.106483

Shih, J. J., Krusienski, D. J., & Wolpaw, J. R. (2012). Brain-Computer Interfaces in Medicine. *Mayo Clinic Proceedings*, *87*(3), 268–279. https://doi.org/10.1016/j.mayocp.2011.12.008

University of Calgary. (2025). *What is BCI?* Cumming School of Medicine; University of Calgary. https://cumming.ucalgary.ca/research/pediatric-bci/bci-program/what-bci

Wang, Y., Tang, Y., Wang, Q., Ge, M., & Xu, S. (2025). Advances in brain computer interface for amyotrophic lateral sclerosis communication. *Brain-X*, *3*(1). https://doi.org/10.1002/brx2.70023

Zhang, X., Ma, Z., Zheng, H., Li, T., Chen, K., Wang, X., Liu, C., Xu, L., Wu, X., Lin, D., & Lin, H. (2020). The combination of brain-computer interfaces and artificial intelligence: applications and challenges. *Annals of Translational Medicine*, *8*(11). https://doi.org/10.21037/atm.2019.11.109