Summary 2

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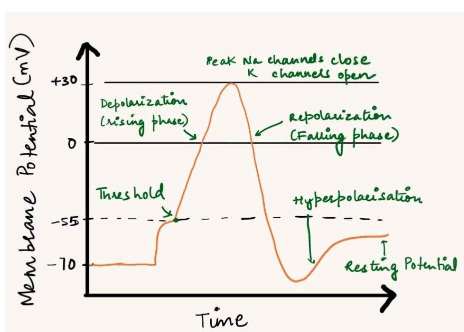
Why do we need the brain?
The primary function of the brain is to produce adaptable and complex movements. Sea squirts digest their brain once they become immobile. A child is able to defeat a robot in terms of dexterity but the same cannot be said for cognition.The brain minimizes movement uncertainty by integrating sensory input with prior knowledge, predicting outcomes, and canceling expected sensations(explains why self-tickling fails).

Brain Structure: The brain has ~86 billion neurons and ~10^{14} synapses, forming an incredibly dense and dynamic network.The brain consists of two mirror-image hemispheres, with communication channels between them but are mostly independent. The sagittal section involves cutting the brain along the midline and looking sideways. It consists of three regions: the forebrain (cognition, sensory processing, homeostasis), midbrain (sensory-motor integration), and hindbrain (vital functions, coordination). Forebrain is enlarged in humans compared to monkeys which is a sign of evolution.

Cytoarchitecture of the Cerebral Cortex: The cerebral cortex in the forebrain is organized into six layers made of white and grey matter. The cortex is the brain's outer layer composed of gray matter with folds (gyri) and grooves (sulci) that increase surface area. The lateral sulcus separates the temporal lobe from the frontal and parietal lobes, while the central sulcus divides the frontal (motor) and parietal (sensory) lobes. These layers interact differently based on their region of the brain—either within the same region or between different regions. This structure forms a microcircuit that is replicated across various parts of the brain, ensuring consistent patterns of communication.Neurons transmit signals, astrocytes support, oligodendrocytes insulate, and microglia provide immunity.

Neural Communication: Neurons have cyton, axon and nerve terminals.The cyton has dendrite which receives the signal.The space between two neurons is called synapse. Neurons communicate via synapses, where neurotransmitters (chemical messengers) relay signals. Glial cells support this process, maintaining the brain's environment.A neuron at rest maintains a charge of -70 mv. When stimulated reaches -55 mV, triggering depolarization(Na+rushes in making inside positive).After peaking around +30mV, repolarization (K+exit)occurs. The neuron briefly hyperpolarizes before returning to -70mV.



We can listen to action potential via a wire. When a neuron receives a sufficiently strong signal (such as from an external current), its membrane potential becomes positive, and an action potential (electrical impulse) is generated.

Speed of communication in neurons: The brain processes signals rapidly, aided by myelin sheaths that insulate neurons and enhance signal transmission. Neural activity can be observed by detecting voltage changes from firing neurons, which can be amplified and converted into sound.

Visualizing Neural Activity: Raster plot is the individual spike timing across trials.Peri-stimulus histogram shows the averaged spike frequency around a stimulus.

Electrocorticography (ECoG) vs. EEG: ECoG records brain activity using electrodes placed directly on the brain's surface, capturing both extracellular(affecting surrounding neurons) and intracellular(focused on a single neuron) signals. EEG, a non-invasive alternative, records from the scalp but with lower resolution. EEG signals are in the microvolt range, while larger movements like eye blinks generate millivolt signals.

Brodmann Areas and Brain Structure: They are regions classified by their cellular structure rather than function. Each area has distinct neuronal patterns, with Area 4 controlling motor function and Area 17 linked to vision.

Motor and Sensory Homunculus: Different strips of brain responsible for motor and sensory functions.

Electroconvulsive Therapy and Neuroplasticity: The process of sending current (such as via a wire) into the brain can induce neuronal firing. Neuroplasticity is the brain's ability to reorganize and form new connections in response to stimuli, injury, or learning. ECT can trigger neuroplastic changes.

Brain-computer interfaces (BCIs): It enables direct brain-to-device communication, bypassing damaged motor pathways to restore movement or communication in paralysis patients.

Neuronal Response to Numbers (Numerosity): Certain neurons in the ventral intraparietal area (VIP) of the parietal cortex respond to numbers, even without visual input. These neurons help process numerical information conceptually across sensory modalities, such as vision or sound. Studies in monkeys show that the VIP is crucial for numerical memory and quantity recognition.

Neurons Controlling Fine Movements (Motor Cortices): The motor cortex controls movement, with more neurons dedicated to fine motor tasks (hand movements) than coarse ones (e.g., leg movements). This reflects the greater precision needed for dexterous tasks compared to basic leg motions.

Gap in conduction and reaction time : Conduction time refers to how long it takes for a neural signal to travel down an axon. Action potentials can reach speeds of 40 ms +20 ms, varying by neuron type and distance. Reaction time (~200 ms) is the delay between perceiving a stimulus and responding. This delay is due to higher-order processing, decision-making, and motor planning. Response times fluctuate across trials due to factors like attention, emotional state, and neural variability. Voluntary actions (e.g., pressing a button) take longer than reflexive responses (e.g., blinking) because they involve decision-making and motor planning.The brain can delay immediate reactions to allow for better decision-making, crucial in uncertain situations. For example, in assessing a potential threat, withholding a response provides time for evaluation.

Latency and Vision: It is the delay in processing and prioritizing stimuli. In dynamic environments, the brain must quickly determine which inputs are critical, enabling faster responses to relevant information, such as a potential threat or movement in the visual field. The brain does not treat all sensory input equally, focusing more on stimuli that may require action.

Saccadic Eye Movements: They are rapid, jerky shifts that occur about 3 times per second, allowing the eyes to quickly sample the environment. These movements, lasting only 20–50 milliseconds, help us gather visual information by shifting attention between fixation points. During saccades, visual processing is suppressed, making fixation phases crucial for perceiving details. This rapid scanning allows efficient monitoring of dynamic environments.

DBS for Parkinson's Disease: Deep Brain Stimulation is a surgical treatment for Parkinson's disease that involves implanting electrodes into specific areas of the brain to deliver electrical impulses, helping regulate abnormal brain activity. It is typically performed while the patient is awake because the targeted brain regions do not have pain receptors. Local anesthesia is administered, but the patient stays conscious to allow the doctors to test the effects of stimulation in real time, adjusting parameters to optimize the treatment's efficacy. DBS reduces motor symptoms of Parkinson's, such as tremors, rigidity.

Mice Pressing Lever for Dopamine: Lever pressing for dopamine is a behavioral experiment where mice are trained to press a lever to receive a reward, typically in the form of dopamine, a neurotransmitter critical for pleasure and reward. In these experiments, the action of pressing the lever is linked to dopamine release in the brain.To obtain dopamine, mice often must make trade-offs, such as sacrificing access to food or water, demonstrating how the brain prioritizes reward-seeking behavior, this often results in death of mice. This setup illustrates the brain's motivation system, highlighting the role of dopamine in reinforcing behaviors and influencing decision-making processes.

Visual Prosthesis: Device designed to restore vision in individuals with blindness or severe visual impairments. These devices can include retinal implants, which directly stimulate the retina, or cortical implants that interact with the visual cortex.

Visual Field and Neuron Activation: Neurons in the visual system respond to stimuli within their receptive fields, specific areas of the visual field where a stimulus triggers a response. When motion occurs within this field, neurons become activated, as they are sensitive to changes, especially motion, which is crucial for survival (e.g., detecting predators or prey). The visual field refers to the area visible without moving the eyes, and the brain continues processing visual information from this area even when the eyes are still.

Random Dot Kinetogram (RDK): It is one in which there are dots moving on the screen. Some of the dots are moving in a particular direction, while the others are moving randomly. The participant has to figure out the overall direction. Initially the participant focuses on the screen, then the targets appear and start their motion. The participant will take time to figure out the movement and that can be characterised by the saccadic motion of their eyes, which try to follow the movement of the dots. Researchers adjust the number of dots moving coherently to manipulate the difficulty. By titrating this, they can measure the minimum number of moving dots needed to perceive motion. This can help us study decision making, motion perception and vision.

BCI to help people speak: It can assist individuals with speech impairments, such as those caused by conditions like ALS or stroke. BCIs work by detecting brain signals related to speech intentions and translating them into text or synthesized speech.

Artificial Skin for Sensory Feedback in Prosthetics: Embedded with pressure sensors that convert physical touch or pressure into electrical signals, which are then sent to the brain.