Neurology lesson 2
23/10/2025

Motor system

The Motor System is the complex network of structures in the brain, brainstem, spinal cord, and peripheral nerves that are responsible for producing **movement**. It's much more than just telling a muscle to contract; it involves a sophisticated sequence of mental processes and neural commands.

A. Core Components of Motor Function

Motor function can be broken down into four essential stages that result from an ongoing, integrated process:

1. **Ideation**: The initial thought or desire to move (e.g., "I want to grab that cup"). This occurs in association areas of the cerebral cortex.
2. **Planning**: Determining *how* the movement will be performed, including the sequence, timing, and force required (e.g., deciding the trajectory, speed, and grip strength for grabbing the cup). This primarily involves the **premotor** and **supplementary motor areas** of the cortex, along with the **basal ganglia** and **cerebellum**.
3. **Execution**: Sending the final neural signals down the spinal cord and out to the muscles to make the movement happen. This is initiated by the **Primary Motor Cortex (M1)**.
4. **Control and Correction**: Continuously monitoring the movement as it occurs using sensory feedback (somatosensory system) and adjusting it instantly to ensure accuracy (e.g., fine-tuning the grip strength as the cup is touched). The **cerebellum** is critical for this real-time control.

B. Functional Integration of Key Structures

Movement is the result of a complex functional integration between three main control centers:

- **Motor Cortical Areas**: The command center, responsible for **ideation, planning, and initiating** conscious, voluntary movement.
- **Basal Ganglia**: A set of deep nuclei that act as a filter and regulator. They are essential for ensuring the **smoothness of movement** and the **suppression of unwanted, involuntary movements**.
- **Cerebellum**: The "error correction" system. It does not initiate movement but coordinates and controls ongoing movement, ensuring accuracy, balance, and precision.

C. The Two-Neuron Chain: UMN vs. LMN

The entire motor pathway is conceptually divided into two major classes of neurons that form a continuous chain from the brain to the muscle:

1. Upper Motor Neurons (UMNs)

- **Definition**: These neurons originate in the **primary motor area (M1)** of the cerebral cortex or in specific brainstem nuclei.
- **Function**: They are the **command neurons** that carry the motor signal from the brain **down to the spinal cord or brainstem**.
- **Anatomy**: Their axons form the major descending motor tracts, most famously the **corticospinal tract** (which controls voluntary movement). They do **not** directly contact the muscle.

2. Lower Motor Neurons (LMNs)

- **Definition**: These neurons originate in the **motor nuclei of the brainstem** (for cranial muscles) or in the **anterior horns of the spinal cord** (for trunk and limb muscles).
- **Function**: They are the **final common pathway**. Their axons leave the CNS and travel out through peripheral nerves to activate (innervate) skeletal muscles, causing them to contract.
- **Activation**: The activation of any skeletal muscle ultimately occurs only through its LMN.

Feature	Upper Motor Neuron (UMN)	Lower Motor Neuron (LMN)
Location of Cell Body	Cerebral Cortex or Brainstem	Spinal Cord (Anterior Horn) or Brainstem (Cranial Nerve Nuclei)
Target	LMNs in the spinal cord/brainstem	Skeletal Muscle Fibers
Tract	Corticospinal, Corticobulbar, etc.	Peripheral Nerves
Clinical Damage	Causes UMN Syndrome (Spasticity, Exaggerated Reflexes)	Causes LMN Syndrome (Flaccidity, Atrophy, Reduced Reflexes)

Upper Motor Neuron (UMN) System and Syndromes

This section focuses on the **Upper Motor Neuron (UMN)** system, which is where conscious, voluntary movement originates and is planned. It details the main brain areas involved, the primary descending pathway, and the distinct clinical presentation of a UMN injury.

A. Cortical Motor Areas

The primary commands for movement are generated in the cerebral cortex:

- Primary Motor Area (M1):
  - **Location**: Found in the **precentral gyrus** (Brodmann area 4).

    - **Function**: This is the main starting point for motor execution, responsible for sending the direct signal for movement.
    - **Motor Homunculus**: M1 contains a spatial map of the entire body, called the **motor homunculus**. This map represents the **contralateral body** (the opposite side). Like the sensory homunculus, the parts of the body requiring **fine, complex movements** (like the hands, face, and tongue) occupy a disproportionately large area of the cortex.

- Non-Primary Motor Areas :
    - **Premotor Area (PM)**: Plays a role in **coordinating and preparing** voluntary movements and controlling axial (trunk) musculature.
    - **Supplementary Motor Area (SMA)**: Involved in the **programming and coordination of complex motor sequences**.

B. The Corticospinal Tract (The Main Motor Pathway)

The **Corticospinal Tract** is the most important UMN pathway for skilled, voluntary movement of the limbs and trunk.

- Origin : The fibers originate mainly from **M1** and, to a lesser extent, the premotor area (Brodmann area 6).
- **Descent**: The fibers descend through the internal capsule and pass through the midbrain at the level of the cerebral peduncle.
- **Crossing (Decussation)**: At the level of the **medulla oblongata**, most of the fibers (about 80–90%) cross to the opposite side. This is known as the **pyramidal decussation**.
    - The crossed fibers form the **Lateral Corticospinal Tract**, which descends in the spinal cord to control muscles in the distal parts of the limbs.
    - The uncrossed fibers form the **Anterior Corticospinal Tract**, controlling axial muscles in the trunk and proximal parts of the limbs.

C. Other Descending Motor Tracts

While the corticospinal tract is primary for voluntary movement, other brainstem tracts contribute to automatic motor control, muscle tone, and posture:

- **Vestibulospinal Tract**: Helps you **keep your balance**.
- **Reticulospinal Tract**: Controls **muscle tone and posture**.
- **Rubrospinal Tract**: Assists in the **fine control of the limbs**.

D. Upper Motor Neuron Syndrome (UMNS)

This clinical syndrome results from a lesion or dysfunction of M1 or the descending corticospinal tract.

Clinical Feature	Description	
Weakness (Paresis/ Plegia)	Muscle weakness and a reduction or loss of voluntary movement. This loss is particularly noticeable in **fine finger movements**.	
Increased Tone (Spasticity)		**Increased muscle tone**. This is often described as *velocity-dependent* resistance (the faster you try to move the limb, the more resistance you feel).
Exaggerated Reflexes		**Exaggerated deep tendon reflexes**. Since the UMNs normally modulate (dampen) the LMN response, their loss results in overly sensitive reflexes.
Pathological Reflexes	The appearance of abnormal reflexes, such as the **Babinski sign**. Normally, stroking the sole of the foot causes the toes to curl down. In UMNS, the big toe moves upward (extends) and the other toes fan out.	

E. Patterns of Weakness in UMNS

The location of the UMN lesion determines the pattern of paralysis or weakness (paresis):

- **Monoparesis/Monoplegia**: Weakness in **one limb**.
- **Hemiparesis/Hemiplegia**: Weakness of **one entire side** of the body (e.g., left arm and left leg). This indicates a unilateral UMN lesion located **above the pons** (in the cortex or internal capsule).
- **Paraparesis/Paraplegia**: **Bilateral weakness of the lower limbs**. This suggests a bilateral lesion in the **dorsal or lumbar spinal cord**.
- **Tetraparesis/Tetraplegia**: Weakness of **all four limbs**. This is typically caused by a bilateral lesion in the **cervical spinal cord** (C1–T1).

Patients with hemiplegia often display a characteristic **spastic or circumductive gait**, where the affected leg is extended and swung in a circular motion at the hip.

F. Non-Primary Motor Area Dysfunction (Apraxia)

Damage to areas like the premotor or supplementary motor cortex leads to **apraxia**.

- **Apraxia** is the reduced ability to **plan and perform complex motor acts and sequences**.
- Patients with apraxia **do not** have weakness, sensory loss, or attentional deficits. They can perform simple, automatic movements but struggle when asked to execute complex, goal-directed tasks or imitate gestures.
- **Forms**: Includes motor, ideomotor (difficulty imitating gestures), and ideational apraxia (difficulty understanding sequences of actions).