THE SENSORIMOTOR SYSTEM (p.l)

1. **Introduction**

Like the sensory systems, the motor systems are: **hierarchical**,
are guided by sensory (especially somatosensory) **feedback**,
and are changed by the amount of prior practice/**learning**

note: **Ballistic movements** (fast, brief, well-practiced) do not require sensory feedback (e.g. swatting a fly)

note: much of sensory feedback in unconscious (e.g. proprioception)

note: during initial phases of motor learning, performance is under conscious control (cortex, have to "think" about movement a lot); after lots of practice, control of individual movements have become an integrated whole string of motions, now no longer under conscious control and adjusted by unconscious sensory feedback
which is why it is so very **difficult to correct** a faulty golf swing or tennis serve or set of piano/guitar notes or typing error!

CNS areas involved:

Posterior parietal area (association cortex, multisensory integration)
Secondary motor cortex
Primary motor cortex
Brain stem motor nuclei
Spinal motor pathways/circuits
To (alpha, gamma) motor neurons in spinal cord
To ventral spinal nerves --- to skeletal muscles (Somatic NS)

2. **Sensorimotor Association Cortex**

Posterior parietal association area

Supplies information re. location of body parts (to be moved) and re. location of external objects with which body is going to interact
Visual, auditory, somatosensory

2. **<u>Sensorimotor Association Cortex</u>** (cont.)

Posterior parietal association area (cont.)

Sends **output** to: **frontal lobe motor areas**, including:
- To **Dorsolateral Prefrontal association cortex**
- To **Secondary motor cortex**
- To **Frontal eye fields**

Lesions --- Inaccurate reaching/grasping
- Poor control of eye movements
- Inattention to target objects
- **Apraxia** (*S* cannot make a specific movement out of context upon request, but can make this same movement volitionally in context… e.g. pick up that hairbrush) (**bilateral symptoms**, even **after unilateral damage to** only the **left posterior parietal lobe**)
- **Contralateral neglect** (*S* does not respond to any stimuli on the side of the body that is contralateral to the side of the damage)
  esp. severe after damage to **right** posterior parietal area
  --- severe left side neglect

3. **<u>Dorsolateral Prefrontal Association Cortex</u>**

Major receiving area for axons from Post. Parietal Assoc. cortex

This area sustains the **memory of the stimuli** to which the *S* is going to respond

Neurons here fire before the movement is made, **when *S* first makes the decision to move**

Outputs: To **Secondary motor cortex**
- To **Primary motor cortex**
- To **Frontal eye fields**

4. **<u>Secondary Motor Cortex</u>**

Includes: **Supplementary Motor Cortex**
- **Premotor Cortex**
- **Cingulate Motor Areas**

Outputs to: **Primary Motor Cortex**
- **Motor circuits of brain stem** directly

THE SENSORIMOTOR SYSTEM (cont., p.3)

4. **The Secondary Motor Cortex** (cont.)
   Purpose: **to program specific patterns of movements**

5. **The Primary Motor Cortex**
   Also known as the **Precentral gyrus** (anterior to central sulcus)
   Inputs from the Secondary Motor Cortex
   Outputs to the **spinal cord motor neurons**
      Source of final signal to motor neurons to contract --- a movement
      Esp. controls **precise, intricate voluntary movements** of hands, mouth
         Very large area of precentral gyrus is devoted **to fingers, hand, face, lips, jaw, & tongue**
         Relatively smaller area devoted to arms, leg, trunk
         Note**: toes** still get a fairly large amount of tissue, holdover from our primate past

   Lesions --- S unable to move one body part without moving other parts (loses the precision of movement)
   --- **astereognosia** (difficulty recognizing objects by touch)
   --- reduced speed, accuracy & force of movement
   --- but S still above to move (less precise, "clumsy" movements)

6. **Cerebellum and Basal Ganglia**
   motor areas located below the level of the cerebral hemispheres
   help **to fine tune and to coordinate movement** commands in the descending motor pathways
   also are involved in **learning/cognition** beyond role in movement *per se*
   Cerebellum:
      Constitutes only 10% of mass of the brain, but contains more than 50% (some sources say 70%!) of the brain's neurons
         thus, must be made up of many small neurons
      Lesions --- loss of precise control over movements
      --- cannot maintain a steady posture, motor tremors
      --- disturbed balance, gait, speech, eyemovements
      --- unable to learn new motor routines

6. **The Cerebellum and Basal Ganglia** (cont.)

Basal Ganglia:

Caudate nucleus + **Putamen** = Striatum

Putamen + **Globus Pallidus** = Lentiform/Lenticular nucleus

Like the cerebellum, the basal ganglia modulate descending motor commands

Are part of a loop that sends signals (via the thalamus) to and receives signals from various areas of the cerebral motor cortex

e.g. **Parkinson's Disease**:

- tremors in lips, fingers
- slowness of movements
- difficulty initiating a movement
- lack of facial expressions, fixed/staring eyes

7. **Descending Motor Pathways**

Dorsolateral Corticospinal Tract (direct, precise)
Dorsolateral Corticorubrospinal Tract (indirect, precise)
Ventromedial Corticospinal Tract (direct, diffuse)
Ventromedial Cortico-Brainstem-Spinal Tract (indirect, diffuse)

Dorsolateral Corticospinal Tract ("Pyramidal" Tract)

Axons originate from **Betz neurons** in Primary Motor Cortex
- Largest somas of all neurons…why?

Synapse on **interneurons** that then go to **alpha motor neurons** in spinal cord (in ventral horn of grey matter)

Innervate **distal muscles of wrist, hands, fingers, & toes**
- If synapse directly on alpha motor neurons (not via interneurons), can independently move individual fingers (seen in primates, raccoons, hamsters)

Control **very precise, voluntary movements**

Decussates in medulla

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7. **<u>Descending Motor Pathways</u>** (cont.)

Dorsolateral Corticorubrospinal Tract

Primary motor cortex --- **Red nucleus** (midbrain) & then decussates
--- cranial nerve nuclei (esp. CN V Trigeminal, VII Facial, XI Spinal Accessory, XII Hypoglossal)
or --- interneurons in spinal cord which then go to alpha motor neurons in ventral horn of grey matter

Controls **precise movements** of face, head (via CNs), arms & legs
More **distal muscles**

Ventromedial Corticospinal Tract

Primary motor cortex --- **descend ipsilaterally** to several adjacent spinal segments,**bilateral innervation** (interneurons --- motor neurons)

Less precise movement in proximal muscles of legs, arms, & trunk
Including thigh and shoulders

Ventromedial Corticospinal Brainstem Spinal Tract

Primary motor cortex --- descend ipsilaterally to brainstem,
Including **tectum** (colliculi, spatial location), **vestibular nuclei** (CN VIII) (input from semicircular canals, balance), **reticular formation** (complex species-specific movements, e.g. gaits), and **motor nuclei of cranial nerves that control face, throat** (e.g. CN IX, Glossopharyngeal)

Then **descend bilaterally** after brainstem to spinal cord

Controls **less precise bilateral movements of whole body**, several segments of spinal cord, **proximal muscles**

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8. **<u>Sensorimotor Spinal Circuits</u>**

Muscles:

- **Motor units**
- **Neuromuscular junction**, ACh, motor end-plate
- **Motor pool**
- **Fast muscle fiber** (fast to contract, fast to relax)
  - Can generate great force, quick to fatigue, poorly vascularized
- **Slow muscle fiber** (slower to contract, capable of sustained contraction)
  - Weaker force, more richly vascularized
- **Antagonistic muscle pairs** (e.g. flexors and extensors)

Receptor Organs of Tendons & Muscles

- **Golgi tendon organs**
- **Muscle spindle organs**, & **intrafusal** muscle fiber(**gamma** motorneuron)
- **Extrafusal** muscle fibers (actual muscle's fibers)

Other: **Reciprocal innervation** (of antagonistic muscle pairs)

- Role of **inhibitory interneurons** (Renshaw cells)
- Recurrent collateral inhibition
- **Central sensorimotor programs** (some innate, some learned)
  - **Innate ones control species-specific behaviors** (e.g. gaits)
  - **Learned ones involve "chunking" & shift of motor control to "lower" levels in motor systems** (e.g. cerebellum, brainstem structures)