Motor Systems

The perception-action hierarchy

- Brain
- Spine
- Perception (Somatosensory)
- Action (Motor)
Motor Areas of the Brain

- **Subcortical and Cortical**
- **Hierarchical control**
  - Connection between areas with multiple levels of control
  - Higher levels: planning based on experiences and perceptions (lower level isolation leads to simple reflex reactions)

Motor areas of the brain

**Subcortical**
- Cerebellum
- Basal Ganglia

**Cortical**
- Motor cortex
- Premotor cortex
- Parietal cortex
- Supplementary motor area (SMA)
Subcortical Areas: Cerebellum

- 10% of brain mass, more that 50% of neurons
- Input from primary & secondary motor cortex
  - Motor feedback from vestibular and somatosensory systems
- Evaluates and corrects input for ongoing movements
- Major role in motor learning

Damage to the cerebellum

- Trouble with rapid, ballistic movement sequences that require accurate aim and timing
  - e.g., tapping a rhythm, pointing to a moving object, typing, speaking, writing, playing a musical instrument
- Strength is preserved
  - e.g., grasping, lifting
- Difficulty in controlling the angle and distance of eye movements
  - executing saccades to particular location
- Symptoms resemble alcohol intoxication
  - clumsiness, slurred speech, inaccurate eye movements
The finger-to-nose test

- Instructions:
  “Hold one arm straight out and then, at a command, touch your nose.”

- Normally executed in 3 steps
  1. ballistic movement towards the nose
  2. hold (stop) finger just in front of nose
  3. slower movement to touch nose

- Diagnostic of cerebellar damage

Subcortical: Basal Ganglia

- Consists of
  - Putamen
  - Caudate nucleus
  - Globus pallidus (GP)
  - Substantia nigra
  - Subthalamic nuclei (SN)

- Receives input from cortex and transmits back via thalamus
- Nuclei are not a single entity, but interconnected network
Basal Ganglia Pathways

- **Striatum** = caudate + putamen
- Two pathways: **Direct and Indirect**
  - Direct pathway: *increase* thalamic activity through direct inhibition of GPi
  - Indirect pathway: can *increase* thalamic activation (through GPe) or *decrease* it (through STN)

Parkinson’s Disease

- Neurodegenerative disease
  - basal ganglia affected
  - gradual progressive death of neurons in substantia nigra
  - decreased dopamine release into the caudate and putamen

- Symptoms include
  - rigidity
  - muscle tremors
  - slow movements
  - difficulties initiating physical and mental activity
Effect of Parkinson’s Disease

- Loss of dopaminergic fibers of substantia nigra (SNc)
- Reduces inhibitory activity along the direct pathway
- Increased inhibition from the globus pallidus (Gpi/SNr) to the thalamus
- Decrease in cortical activation and movement

Pathology and treatment

- Treatment with L-Dopa, a precursor to dopamine (can cross the blood-brain barrier)

Huntington’s Disease

- Progressive degenerative disorder
- Clumsiness, balance problems and general restlessness (onset)
- Involuntary movements (chorea) gradually take over normal motor function
  - Contorted positions
- Patients develop apraxia, aphasia or agnosia

L-Dopa
- does not prevent loss of neurons
- produces side effects, including restlessness, sleep problems, delusions
Effects of Huntington’s Disease

- **Atrophy**: cell death
  - Basal ganglia: as high as 90% in striatum
- Atrophy leads to pathway changes in striatum
  - Affects **inhibitory neurons** of indirect pathway
  - Leads to **reduced output** from basal ganglia -> **excessive excitation** of thalamus -> uncontrollable movements

Changing view on Basal Ganglia and Cerebellum

- **Traditional view**: Both areas involved in motor control and motor learning
- **Emerging view**: Both areas are involved in motor and non-motor control functions (i.e. cognitive functions)