Physiology
Unit 2

CONTROL OF MOVEMENT
Motor Program

• Pattern of neural activity required to properly perform the desired movement

• Highest level
  – Motor cortex
  – Decide what movement will occur

• Middle level
  – Cerebellum, basal ganglia, thalamus, brainstem, spinal cord,
  – Postures and movements needed to carry out the action
  – Receives sensory input from local level

• Local level
  – Brainstem, Spinal cord
  – Afferent neurons, Motor neurons, Interneurons
  – Monitors muscle length and tension constantly adjusting muscle contraction
Control of Body Movement

Motor Control Hierarchy
Local Control of Motor Neurons

• Local control levels are *relay points* for instructions coming from higher levels in the motor program

• Adjusting motor unit activity to local conditions (obstacles to movement, pain)

• Local control systems use sensory information from sensory receptors
  – Muscles
  – Tendons
  – Joints
  – Overlying skin

*Somatic Nervous System*
Interneurons

- Most of the synaptic input from descending pathways to motor neurons are from interneurons
- 90% of spinal cord neurons
- Integrate inputs
  - Higher centers
  - Peripheral receptors
  - Other interneurons
- Determine which muscles are activated and when
  - Coordinates repetitive, rhythmic activities
    - Walking, running
- Can turn movements on or off
  - Grabbing a hot plate
Reflex Arc

• The basic anatomical/functional unit of the nervous system

• Components:
  1. Sensory receptor
  2. 1\textsuperscript{st} order sensory neuron
  3. Integrating center (brain/spinal cord)
  4. Motor neuron
  5. Effector organ (skeletal muscle, cardiac muscle, smooth muscle, glands)
Reflex Arc Components

1. Sensory receptor
   - Constantly samples its environment
     * Phasic receptors
     * Tonic receptors

2. 1st order sensory neuron
   - Afferent, peripheral; leading to the CNS

3. Integrating/coordinating center
   - Central nervous system
     * Processes all incoming sensory information
     * Integrates sensory information
     * Coordinates motor commands
Reflex Arc Components

4. Motor neuron
   - Efferent, peripheral; leading from the CNS
     • Somatic motor neuron
     • Autonomic motor neuron
       • Sympathetic division
       • Parasympathetic division

5. Effector organ
   - A muscle or a gland that responds
   - Skeletal muscle (somatic)
   - Smooth muscle, cardiac muscle, glands (autonomic)
The Spinal Cord: Reflex Arc

- Controls reflex activity
Local Afferent Input

• Afferent fibers bring information from sensory receptors from
  – Skeletal muscles (*prime movers*)
  – Nearby muscles (*synergists, antagonists, fixators*)
  – Tendons, joints and skin affected by the movement

• Sensory receptors for local skeletal muscle control monitor
  – Length and tension
  – Joint movement
Length Monitoring System

• Muscle spindle stretch receptors
  – Stretch receptors embedded in muscle
• Monitor muscle length
• The more or the faster the muscle is stretched the greater the rate of receptor firing
• Contraction of the extrafusal fibers shortens the muscle and slows down the rate of firing
Alpha-Gamma Co-Activation

- Prevents loss of sensory information when the muscle is contracting
- Alpha motor neurons
  - Extrafusal fibers
- Gamma motor neurons
  - Gamma motor neurons stimulate the two ends of the intrafusal fibers to contract
  - Maintains tension in the spindle apparatus
Tension Monitoring Systems

- Tension depends on
  - Muscle length
  - Load on muscle
  - Degree of muscle fatigue

- Sensory information on tension
  - Vision
  - Somatosensory input
  - Golgi tendon organs

- Inhibitory synapses prevent excessive contraction or passive stretching
Monosynaptic Reflex

- Reflex response that involves ONLY one synapse
- Sensory neuron from the extensor muscle synapses with the motor neuron for that extensor muscle
- Only found in the stretch reflex
Polysynaptic Reflex

- Reflex response that involves **MORE THAN** one synapse
  - Interneurons
- Ipsilateral’s flexor muscle’s motor neuron stimulated
  - Withdrawal reflex
- Opposite limb (contralateral) extended to support the body’s weight
  - Crossed extensor reflex
Control by the Cerebral Cortex

- Planning and controlling ongoing movement
- **Motor cortex, premotor area**
  - Gives rise to most nerve fibers to descending pathways for motor control
- Cortical neurons form a neural network
  - Many neurons participate in each single movement
  - Coordination of many parts to produce a smooth, purposeful movement
Subcortical and Brainstem Nuclei

• Planning and monitoring movement
• Establish the program that determines the specific sequence of movements needed to accomplish a desired action

• **Basal ganglia**
  – Subcortical nuclei
  – Link circuits
    • Some facilitate movements
    • Some suppress movements
Cerebellum

1. Influences balance and posture
   – Input to brainstem nuclei
2. Provides timing signals to the cortex and spinal cord
   – For precise execution of different phases of the motor program
   – Agonist/antagonist timing
3. Coordinates movement involving multiple joints
4. Stores memories of movements
   – Easier to accomplish the next time
Types of Descending Pathways

• Pyramidal Tract (corticospinal pathway)
  – Planning tracts
  – From motor cortex
  – Excitatory

• Extrapyramidal Tract (brainstem pathway)
  – Coordinating tracts
    • Excitatory/Inhibitory
  – From brainstem
  – Coordinate the “plan” from the motor cortex
  – Maintain posture during movement
Descending Pathways
Corticospinal Pathway

- Pyramidal tract
- Nerves from motor cortex terminate in the spinal cord
- Decussation of the pyramids in medulla
- Convergence/divergence
- Control musculature involved in fine isolated movements
  - Hands, fingers
Descending Pathways
Brainstem Pathway

- Extrapyramidal tract
- Nerves in the brain stem terminate in the spinal cord
- Mostly ipsilateral
- Control large muscle groups
  - Posture
  - Locomotion
  - Head, body movements turning towards a stimulus
Muscle Tone

• Muscle Tone
  – Resistance to stretch
  – Tension
  – Elastic properties of muscle, tendons
• Slightly contracted state of muscles even at rest
• Maintained by stretch reflexes
• Function
  – Helps stabilize joints
  – Improves posture
  – Creates optimal length for muscle contraction
• Requires constant sensory feedback to control muscle activity