Neural Basis of Motor Control
Central Nervous System

- Skeletal muscles are controlled by the CNS which consists of the brain and spinal cord.
  - Determines which muscles will contract
  - When
  - How fast
  - To what degree
  - What changes in force from moment to moment
Neuron: Basic Unit of CNS

Axon is the transmitting pole - neuron has only one

Dendrites are receiving pole - neuron may have none to 1000 dendrites
Neural Transmission

• Each axon is enclosed in cellular (myelin) sheath of lipid material that insulates the axon.
• The sheath is wrapped with sheath cells from CNS and Schwann cells from the peripheral nervous system (PNS).
• The sheaths wrapped together in many layers is called myelinated fibers. If it is only wrapped in one layer it is called unmyelinated fibers.
• Large myelinated fibers (1-2 mm) contain gaps called nodes of Ranvier.
• The myelinated fibers transmit neural messages up to 400 feet per second by jumping from one node to the next. Unmyelinated fibers transmit messages up to 3 feet per second.
Myelin Sheaths

- Dendrites
- Soma
- Cell Nucleus
- Nodes of Ranvier
- Oligodendrocyte
- Presynaptic Terminals
- Myelin Sheaths
- Axon (covered by myelin sheath)
What turns the neural system on!

- The on or off position is determined by the distribution of charged particles (ions).
- Ions, having + or – charges, surround the inside and outside of each cell.
- When there is an unbalanced # of + or – ions on each side it creates a membrane potential.
  - Resting membrane potential (*polarization*)
    - Unexcited cell
  - Action membrane potential (*depolarization*)
    - Excited cell
    - Sodium (NA+) rushes which turns the cell on!
    - Transmission occurs as an “all or none” situation
At rest, potassium ions (K+) can cross through the membrane easily. Chloride ions (Cl-) and sodium ions (Na+) have a more difficult time crossing. The negatively charged protein molecules (A-) inside the neuron cannot cross the membrane. The resting membrane potential of a neuron is about -70 mV (mV=millivolt) - this means that the inside of the neuron is 70 mV less than the outside.
A stimulus first causes sodium channels to open. Because there are many more sodium ions on the outside, and the inside of the neuron is negative relative to the outside, sodium ions rush into the neuron.

Remember, sodium has a positive charge, so the neuron becomes more positive and becomes depolarized. It takes longer for potassium channels to open. When they do open, potassium rushes out of the cell, reversing the depolarization. Also at about this time, sodium channels start to close. This causes the action potential to go back toward -70 mV (a repolarization). Gradually, the ion concentrations go back to resting levels and the cell returns to -70 mV.
How does it transmit from one cell to another?

Neural chains are created called synaptic transmission. Without a synapse there is no communication between neurons and target site such as muscles. There is not an all or none transmission at the junction (transmission may blocked, reduced, amplified or changed). Consists of pre-synaptic neuron (axon button), synaptic cleft, and post-synaptic neuron (receiving axon).
The neurotransmitter is manufactured by the neuron and stored in vesicles at the axon terminal.

When the action potential reaches the axon terminal, it causes the vesicles to release the neurotransmitter molecules into the synaptic cleft.

The neurotransmitter diffuses across the cleft and binds to receptors on the post-synaptic cell.

The neurotransmitter molecules are released from the receptors and diffuse back into the synaptic cleft.
Synaptic Transmission

Presynaptic neuron releases a chemical transmitter.

Transmitter influences the communication

Transmitter can be excitatory or inhibitory.

Most common transmitter is acetylcholine.

Last neuron in the chain is known as the *Efferent Neuron* or motor neuron which end at Muscles neuro-effector junction

Efferent Neurons transmits messages from the CNS and/or brain to muscles.

Afferent neurons or sensory neurons transmit to the brain and spinal cord.
The Brain

- **Hindbrain**
  - Pons
  - Cerebellum
  - medulla
- **Midbrain**
  - Reticular formation
- **Forebrain**
  - Cerebral hemisphere
  - Basal ganglia
  - Hypothalamus
  - thalamus
Hindbrain

- Medulla
  1. Ascending sensory-fiber tract and descending motor track connects the brain to the spinal cord.
  2. Controls heart beat, regulates respiration, and gastrointestinal functions

- Pons
  1. located just above the medulla
  2. Contain neurons that is control movement
  3. Connect the two hemispheres of the cerebellum
  4. Acts as a relay for the auditory system and movement

- Cerebellum,
  1. just behind the medulla,
  2. greatly contributes to the control of movement.
  3. Regulates the quality of movement
  4. Regulates posture
  5. It detects errors and corrects errors in movement
Midbrain

Located just above pons and contains the reticular formation

Plays a major role in arousal, consciousness, states of sleep, and relaxation

Facilitates reflexes of flexion and extension
Forebrain

- Corpus callousum divides the forebrain into two cerebral hemispheres which make up the cerebral cortex.
- Basal ganglia is believed to facilitate movements involving power, speed, direction, and amplitude in movement preparation.
- Hypothalamus controls body temperature and regulates carbohydrate energy use.
- Thalamus is a relay station for sensory and motor information that transmits pulses from one cerebral hemisphere to another and interconnects the other areas of the brain.
Cerebral Cortex

**Cerebral cortex** is composed of 4 lobes

- Frontal – contains the motor cortex which controls detailed movement
- Parietal – primary somatosensory projection area & taste
- Occipital – primary visual projections area
- Temporal – auditory visual projection area, speech & smell

[Next Slide]
Cerebral Cortex
Cerebral Cortex
Motor Control of Goal Oriented, Voluntary Movement or Tasks

*What to do* (declarative knowledge) is a brain function of planned movement.

- Involves both the **limbic** and **association cortex systems** that includes the frontal and temporal lobes of the cerebral cortex, the thalamus, and hypothalamus, and nerve fibers.

- *In short, limbic and association cortex function cooperatively to guide goal-directed voluntary movements.*
Limbic system controls behaviors including emotions, motivation, and learning which provides impetus for goal directed movement in environmental contexts.
Association Cortex

Association cortex system identifies, chooses, and integrates information for distribution to the highest levels of cortex.
Motor Control of Goal Oriented, Voluntary Movement or Tasks

*How to do it* (procedural knowledge) is another brain function associated with planned movement.

- The projection system provides detailed motor and sensory information of how to do it to match what to do (limbic or association cortex systems) in the situation in which the movements or skill is to be performed.

- Includes the basal ganglia, cerebellum, and the motor cortex.
Transportation of sensory information to the brain

- Sensory neural pathway (ascending track)
  - Passes through the spinal cord to brain stem to thalamus to sensory sensory areas of cerebral cortex and to the cerebellum
  - There are different specific ascending tracks
    - Vision has its own track to the cerebral cortex
    - Audition has its own track to the cerebral cortex
    - Sensory information has its own tracks to the cerebral cortex.
  - Ascending tracks cross at the brain stem from one side of the body to another which means information from one side of the body is received in the opposite side of the brain.
Visual Track
Sensory Track

Dorsal Column Route
- touch, pressure, proprioception to the cerebral cortex

Spinothalamic Route
- pain and temperature to the cerebral cortex
Transportation of Movement information from the Brain to the Muscles

• Transport of movement information (descending track) that will execute the movements:
  – Via two distinct motor neural pathways that function together
    • Pyramidal
      – Transmits neural information that arises from the cerebral cortex with axons projecting into the spinal cord that cross over to the opposite side of the body.
      – Primarily associated with fine motor skills.
    • Extrapyramidal
      – Transmits neural information that arises in the brainstem with axons descending into the spinal cord with many of fibers not crossing over to the opposite side of the body.
      – Primarily associated with postural control and muscle control of flexion and extension of hands and fingers.
End of Neural Transmission

- Motor neural information ends at the motor unit.
  - Motor unit innervates the muscle fibers via the Alpha motor neuron
  - The Alpha motor neuron connects to the middle of muscles fiber (neuromuscular junction)
  - At this junction is where nerve impulses are transmitted to the muscle fiber producing muscle contraction
  - When alpha motor neuron activates, all the muscle fibers to which it connects contracts.
  - Greater the number of motor units activated (recruitment), the greater the amount of force the muscle can exert.
Performing a Goal Oriented, Voluntary Movement

- Initial intent to perform a movement
- Performer is receiving and analyzing neural inputs from various sensory inputs originating within the body and externally from the environment.
- Performer monitors carefully all the sensory inputs to prepare for any environment changes that might occur that will effect their movement.
- Once a decision to move has been made, the process of planning continues with a general plan of action.
- General plan of action is influenced by previous experience with the movements, movement situation, initial evaluation of inputs, choices of movements, and the task to be or being performed.
- Once the general action plan has been executed, the performer begins to add detail to the movement, that is, performer selects various movement parameters (force, velocity) necessary to achieve the goal of the movement.
- Also, the performer must consider the environmental context. The environmental variables like distance from ball and/or size of the target must be recognized or the plan of action will fail.
- When the specific plan of action is finally performed, that is movement is produced, the performer evaluates the movement via feedback from within or externally. If the performer cannot recognize sensory-movement based feedback the future action plan will be constrained.
Key Players in Developing and Executing the Plan of Action

• Developing and executing a plan of action involves the limbic, associative cortex, the projection system and spinal system.
  – Limbic system is associated with the intention to act which includes one’s level of motivation, general idea of the movement, and being able to recall or remember past movements.
  – Recognition, selections, and integration of sensory information relevant to action plan needed by the performer and about the environment involves the association cortex.
Who determines how the action plan will be carried out?

• The projection system found in the midbrain determines how the action is to be carried out!

• Basal ganglia, a structure of the projection system, prepares the performer for movement by providing a level of postural stability and providing information about size of the intended movement.
Who controls the plan of action?

- Cerebellum plays a vital role in controlling the plan of action.
  - helps detect errors in a movement
  - helps in changing the movement plan
- Motor cortex
  - Responsible for integrating visual, auditory, and proprioceptive inputs critical to eye-hand coordination
  - Advanced planning and coordination of complex bimanual and bilateral movement sequences
  - Links working and long term memory
Transmission of the Plan of Action

Once the plan of action is conveyed to the system, the alpha motor neurons carry the information out to the muscles via the pyramidal and extrapyramidal descending tracks.
The End